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Chapter 10
Old growth and dead wood as key factors for nature conservation in managed forests. Basics and practice

Harald Schaich, Thomas A.M. Kaphegyi, Rudolf Lühl, Nicole Schmalfuß, Mattias Rupp, Thomas Waldenspuhl, Werner Konold

Introduction

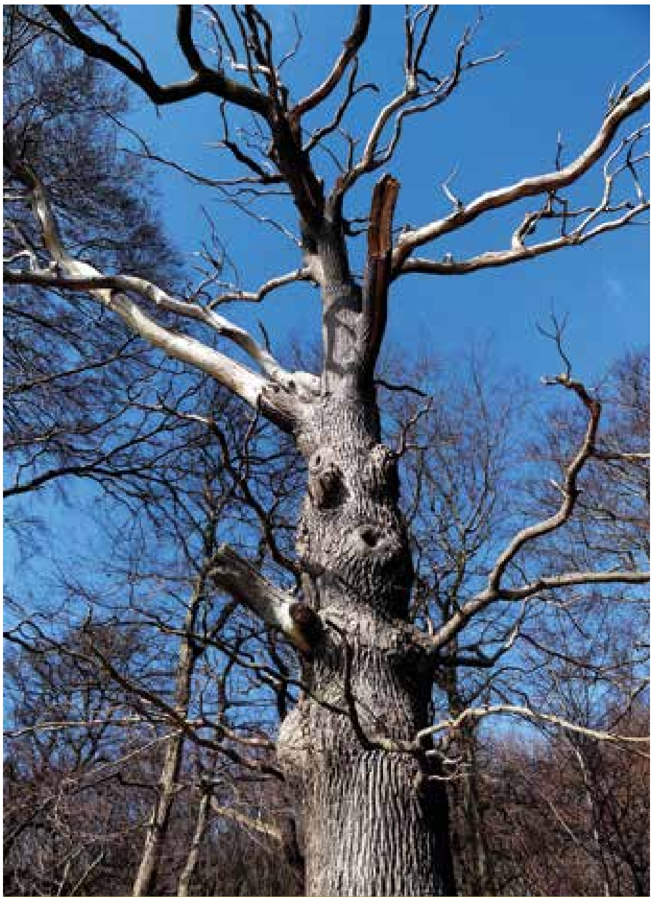
Globally, forest biodiversity conservation is concentrated on the halting of primary forest harvesting and degradation by enlarging the area of undisturbed natural forest ecosystems in protected areas (FAO, 2011). At present, the Convention on Biological Diversity (CBD) aims at incorporating at least 17% of the terrestrial surface worldwide – including the most representative forest biomes – into a network of protected areas (Convention on Biological Diversity, 2010). In Europe however, forests have been shaped by humans for centuries and in most regions almost no remnants of primary forests remain. Consequently, the form and intensity of forest management is – in addition to other parameters – one of the prime factors threatening the conservation of forest habitats and species in Europe (Brunet et al., 2010). At the same time, certain traditional forest management practices, e.g. woodland grazing or coppicing, have created structurally rich forest stands, which could also be very valuable for biodiversity conservation and the provisioning of forest ecosystem services (Gross and Konold, 2010; Plieninger et al., 2011).

In this context, setting aside semi-natural forests in strictly protected areas to allow for natural dynamics in forest development is only one measure to conserve forest biodiversity in Europe. Protected areas should be complemented by other approaches, which focus on the incorporation of biodiversity requirements into forest management (Bauhus et al., 2009; Schaich and Konold, 2012), on the reestablishment or mimicking of traditional forest management systems (Rotherham, 2013; Suchomel et al., 2013), and on the restoration of structural complexity and site-adapted species in non-natural secondary forests like conifer plantations (Zerbe, 2002). In Germany, the goals of the CBD have been taken up in the federal government's National Strategy on Biological Diversity (BMU, 2007). It aims to protect 5% of the total forest area in strict protected areas, but also strives to foster an ambitious guideline strategy for close-to-nature forest management in public forests, to revive traditional forest management systems and to implement payment schemes for nature conservation management in 10% of the privately owned forests by 2020.

Close-to-nature approaches to forest management emerged in European public forests in the second half of the twentieth century as a response to the ecological and economic problems created by the prevailing even-aged, pure and relatively young forest stands (Schütz, 1999). Close-to-nature forestry generally comprises management approaches to enhance continuous forest cover, stands with site-adapted and mixed tree species, uneven-aged stand structures, selective harvesting and the use of natural tree regeneration (Larsen and Nielsen, 2007). Beyond classical close-to-nature management approaches, further objectives of nature conservation have to be considered if managed forests are to host a high level of biodiversity and provide a broad array of ecosystem services. Such additional objectives are the conservation of largely undissected forest areas on ancient woodland sites, the avoidance of mechanical disturbance and chemical pollution of forest soils, the development of ecologically valuable forest edges, the enhancement of more open forest stands and traditional forest management practices, the augmentation of late successional phases and old growth features, and the fostering of a semi-natural amount of dead wood (Schaich and Konold, 2005).

In fact, one of the most pressing problems for forest biodiversity conservation in managed forests is the scarcity of late successional phases and old growth as well as the lack of dead wood in the form of coarse woody debris and snags (Lindenmayer et al., 2006; Nilsson et al., 2003). In primary forests, very old trees and dead wood have been ubiquitous (Keddy and Drummond, 1996). Although amounts of old growth and dead wood vary constantly according to the successional phase of forest development, there has hardly been a primary forest without old trees and dead wood (Nilsson et al., 2003). In managed forests, trees are harvested as long as they can be sold as valuable timber, which is long before they develop structures of maturity, such as dead branches in the crown or wood decay or others. In times of rising energy prices worldwide, timber of minimal quality as well as wood and branches of small dimensions are increasingly extracted from managed forests for the bioenergy sector in Europe (Plieninger et al., 2009).

Old growth and dead wood offer a larger spectrum of habitats such as stem holes, wood in varying degrees of decay, as well as dead branches in the crown or bark hollows (Photograph 1). As such, a huge number of species depend on these resources, for instance hollow-nesting birds or saproxylic beetles (Müller et al., 2007), but also mammals like bats or dormice, amphibians, fungi and mosses (Chambers, 2002; Raabe et al., 2010). Many of the species that are dependent on old growth and dead wood structures are legally protected via Annex II and Annex IV of the EU Habitats-Directive or national laws. As a consequence, many researchers have been working on threshold values, which have to be considered in order to conserve dead wood dependent species guilds in managed forests located in different biogeographic regions (Keddy and Drummond, 1996; Lonsdale et al., 2008; Müller and Bütler, 2010). However, over the past years the amount of old growth and dead wood resources has only been marginally affected by close-to-nature management approaches (Schaich and Plieninger, 2013). As a consequence, managed forests in Germany often do not fully comply with the demands concerning structural complexity that are formulated in the German and European Union biodiversity strategies (BMU, 2007; European Commission, 2011). New practical guidelines and incentives, particularly for the enhancement of old growth and dead wood resources in public and private forests, are therefore needed. Building on empirical evidence from research projects and on a strategy for practical forest management, this chapter aims to enhance knowledge on basic interactions between old growth features, dead wood, forest management, and forest biodiversity as well as to explore practical approaches to foster such habitat resources in managed forest ecosystems. Taking the regional perspective of southwestern Germany (federal state of Baden-Württemberg), the chapter presents: basic attributes by which to classify old growth and dead wood features in forest ecosystems; outlines the actual status of regional old growth and dead wood resources in Baden-Württemberg in relation to spatial and institutional aspects; highlights the role of traditional forest uses such as woodland pasturing for the conservation of old growth features; analyses the importance of habitat trees for biodiversity and especially hollow-nesting birds; and introduces an operational strategy to foster the quantity and quality of habitat trees and dead wood in managed state-owned forests. In a brief synthesis, we derive practical and policy recommendations on how to foster old growth and dead wood features in complex, human-shaped forest landscapes and how to synchronize this important issue with other goals of ecosystem services provisioning in European forests.



Photograph 1: A decaying old growth oak offers plenty of habitat structures (H. Schaich).

The role and attributes of old growth and dead wood in forest ecosystems

Numerous scientific studies have demonstrated the vital role of old growth and dead wood as habitats for fauna and flora of temperate forest ecosystems. Estimates based on empirical case studies suggest that 20% of all fauna in Central Europe rely on old growth and dead wood features and every fourth native beetle species is dependent on dead wood (Schiegg, 1998; Similä et al., 2002). Consequently, there is a close relationship between the amount of old growth and dead wood features in managed forests and species richness as well as abundance of certain threatened species in forest ecosystems (Scherzinger, 1996). In addition, old growth and dead wood is also important for the functioning of forest ecosystems and the provisioning of different ecosystem services such as nutrient cycling, soil development, water storage and regulation of the local climate (McComb and Lindenmayer, 1999). In mountainous regions, dead wood also helps to prevent erosion and facilitates natural regeneration via seedling establishment on and around downed logs (Scherzinger, 1996).

To assess their contribution to biodiversity conservation objectives and ecosystem service provisioning in forests, it is necessary to consider different attributes of old growth and dead wood features. In this respect, the total amount of old growth and dead wood is a central attribute, but it is also important to have information on their quality and their spatial distribution and temporal dynamics (Schaich and Konold, 2005).

Amount of old growth and dead wood

Differences in the amount of old growth and dead wood in primary forests depend on the natural forest type, the age of the forest, the relative area of the different age classes and successional phases, site productivity and likeliness of natural disturbances (e.g. windthrow) (Keddy and Drummond, 1996). In his studies of primary forests in Slovakia, Korpel (1997) detected in beech forests on productive sites a mean value of 200 m^3 ha^{-1} of dead wood, however, the total amounts in single stands ranged from 50 m^3 ha^{-1} (during the optimal phase of forest development) to 310 m^3 ha^{-1} during the decay phase. In their analyses of European primary forests, Nilsson et al. (2003) found a mean number of 50-100 old trees with diameters at breast height (DBH) over 40cm including all forest types and different sites. Excluding the factors of extreme events and single late successional phases, there is a direct correlation between the amount of old growth trees and dead wood features and the site productivity in primary forest ecosystems (Korpel, 1997; Nilsson et al., 2003). Taking into account the demands of old growth and dead wood colonizing species guilds, several authors consider a proportion of 10% of the mean dead wood volume of the respective primary forest on the specific sites as the minimum amount for a managed forest stand to make a contribution to forest biodiversity conservation; a proportion of 50% is regarded as an optimum contribution (Keddy and Drummond, 1996; Korpel, 1997). This is in accordance with recent research results and recommendations that demand thresholds of >20-50 m^3 ha^{-1} (Müller and Bütler, 2010) and 5-10 habitat trees ha^{-1} (with DBH > 40 cm) (Flade et al., 2004; Reif et al., 2001) as minimum values to conserve threatened species that are dependent on old growth and dead wood features in lowland beech forest types.

Photograph 2: Coarse woody debris of different sizes in a mixed beech stand (W. Konold).

Photograph 3: Standing dead willow log offering lots of habitat structures (W. Konold).

Quality of old growth and dead wood

The usability of old growth and dead wood features for specialized species and the respective value for biodiversity conservation also depend strongly on qualitative factors. Here, decisive factors include the dimension, form, tree species, and degree of decay as well as the exposition and microclimate of the respective dead wood or old growth feature (Schaich and Konold, 2005). Many species of insect and bird fauna depend on relatively thick old and dead trees. Therefore 20-25 cm DBH is regarded as the minimum dimension of dead wood stems that could be valuable for biodiversity conservation. However, several beetle species as well as hollow-nesting birds can only use old and dead trees starting from a DBH of between 40-60 cm (Köhler, 1999; Nilsson et al., 2003). The abundance of additional microstructure like dead branches also increases proportionally with larger dimensions (Michel and Winter, 2009). As such, it is also very important to have a suitable number of large old growth trees with > 70 cm DBH within the stand. Nilsson et al. (2003) found the typical number of 10-20 old growth trees with > 70 cm DBH per ha in European primary forests and even up to

30 individuals in primary beech forests. Regarding dead wood, the form as standing dead wood (snag) or fallen log (coarse woody debris) (Photograph 2) is also essential to ensure habitat usability for different species. Snags of large dimensions are a particularly important structural element for saproxylic beetles and hollow-nesting birds and mammals (Photograph 3), however, these are largely absent in managed forests (Scherzinger, 1996). Different fauna species are adapted to colonise specific species of old and dead wood and even a specific degree of decay (McComb and Lindenmayer, 1999). The degree of decay and the special habitat niche is again significantly influenced by the exposition and microclimate of the respective old growth and dead wood individual. In this respect, central recommendations are to provide a species proportion of old growth and dead wood according to the proportion of prevalent tree species within the respective forest stand, and to provide a huge range of different degrees of decay in dead wood features to maximise the colonization potential for different species groups.

Photograph 4: Calcareous beech forests dominating on the Jurassic sediments of the Swabian Alb (low mountain range of south-western Germany) (H. Schaich).

Dynamics of old growth and dead wood supply

The supply of old growth and dead wood features in an undisturbed forest stand depends on the successional phase of forest development as well as on the intensity and frequency of external disturbances (Korpel, 1997; Nilsson et al., 2003). In undisturbed forested landscapes of a significant size there is continuous, though spatially dynamic, supply of large old growth and dead wood resources that guarantees the typical structural diversity of a certain forest type. However, in managed forests, the spatial distribution of old growth and dead wood elements must be recognized to enable permeability and mobility of dependent species on a stand and a landscape scale (Reif et al., 2001; Schiegg, 1998).

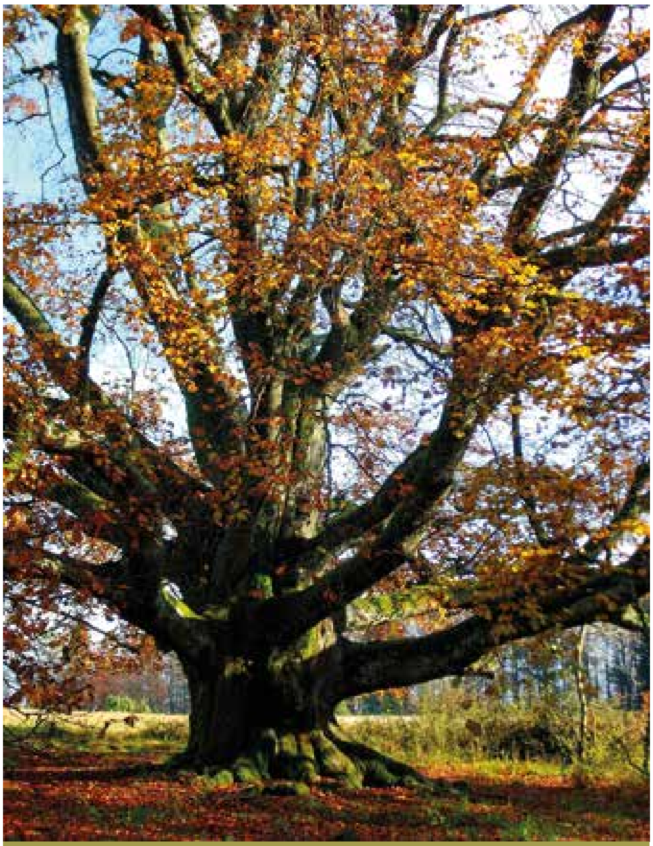
Forest area, ancient woodlands, old growth and dead wood in Baden-Württemberg (southwestern Germany)

The federal state of Baden-Württemberg is well-forested with a forest area of 39% compared to 31% in Germany as a whole. Large forest areas are in the low mountain ranges of the Black Forest (forest area: 71%), the Odenwald (62%), the Swabian Alb (44%) as well as in the Swabian Keuper region (41%) and the glacially formed foothills of the Alps (27%) (Glaser and Hauke, 2004). Dominant tree species vary according to the respective biogeographic region. The Black Forest, the Odenwald and the southwestern foothills of the Alps are mainly stocked by coniferous forest stands with spruce, fir and pines; regionally, e.g. along the edges of the Black Forest to the Upper Rhine Valley, mixed forest stands with deciduous trees and beech forests are also found. The Swabian Alb as well as the Swabian Keuper region are dominated by calcareous beech forests (Photograph 4) as well as mixed forest stands with maple and ash, and to a lesser degree by oaks as complementary species. In Baden-Württemberg, roughly 40% of the forest area is owned by municipalities and other public bodies (like churches or trusts), 36% is privately owned and 24% is owned by the federal state. Most private forests are small in size: 39% are <5 ha, 31% are between 5-200 ha, and only 30% are >200 ha (Kändler et al., 2005). However, forest ownership distribution varies quite strongly across the region, e.g. in the northern Black Forest one can find a high percentage of state forests while in the southern part private forests of small to medium sizes are prevalent.

Ancient woodlands in Germany can be defined as forest stands which have been stocked continuously with trees over a period of approximately 200 years (Glaser and Hauke, 2004). Despite the definitions of Rackham (1980) and Peterken (1993), who regard woodlands as ancient if they have existed continuously over a period of 300 and 400 years, in many parts of Germany, area-wide historical maps and archive sources for the spatial identification of woodlands have only been available since approximately 1750-1800 (Wulf, 1997). In the Germany-wide study by Felix and Hauke (2004) – drawing on the year 1800 as reference date and on CORINE Land Cover data from the year 1998 – 92% of the forest area of Baden-Württemberg was classified as ancient woodlands, which is considerably higher than 77% for the whole forest area in Germany. The proportion of ancient woodlands is presumably overestimated in the study of Felix and Hauke (2004) as a large scale was applied and small forest patches were only covered starting at a certain size. However, the study was able to compare the relative differences in ancient woodland coverage across Germany. Ancient woodlands are very frequent in the Black Forest (96%) and in the Odenwald (97%), whereas in the Swabian Alb (84%) the proportion is comparably low as – according to Bieling et al. (2013) – many formerly extensively used calcareous grasslands have been afforested with spruce during the last century. The large proportion of ancient woodlands in southwestern Germany means that most of the forests have potentially experienced a relative continuity of basic site characteristics and nutrient and water balances. Concerning biodiversity, this habitat continuity could be a decisive factor in the conservation of several typical and often threatened woodland plant species, which are slow colonizers due to their dispersal traits (Wulf, 1997). However, the classification as an ancient woodland refers only to the continuity of forest cover and does not necessarily mean that all of those stands host large amounts of old growth or dead wood (Peterken, 1993).

According to the results of the Germany-wide forest inventory conducted in 2002, the volume of large trees with >50 cm DBH was 119 Mio m³ (24% of the growing stock) and the volume of large old growth trees with > 70cm DBH was only 20.5 Mio m³ (4% of the total growing stock) in the federal state of Baden-Württemberg (Kändler et al., 2005). When age classes are considered, 89,000 ha of the forest stands have a mean age of >140 years and only 20,500 ha are >160 years, which is equivalent to 6.7% and 1.6% of the whole forest area, respectively. The most important tree species with regards to volume of old growth forest stands of >160 years are oaks (42%) and beech (21%), followed by fir (14%), pine (10%), spruce (10%) and other deciduous tree species (2%). Over all forest stands in the federal state a total volume of dead wood of 12.4 m³ per ha was reported, consisting of 9.4 m³ per ha coarse woody debris – which was recorded with a minimum length of 1m – and only 3 m³ per ha standing dead wood (Kändler et al., 2004). If stands with heavy storm impacts from 1999 are excluded, the total amount of dead wood in the managed forest of Baden-Württemberg decreases to 8.5 m³ per ha (6.3 m³ coarse wood debris and 2.2 m³ per ha), which is clearly below the thresholds that are expected to protect species that are dependent on these resources (e.g. Müller and Bütler, 2010).

In regularly managed forest areas, the silvicultural system, the rotation period and the management intensity are decisive direct influencing factors on the amount of old growth and dead wood remaining in forest stands (Brunet et al., 2010). Forest ownership and the related attitudes and interests of the specific owners were identified as relevant indirect factors influencing the availability of old growth and dead wood (Schaich and Plieninger, 2013). If the mean forest area of Baden-Württemberg is considered, state forests have a higher amount of dead wood (approx. 16 m³ per ha) and a higher proportion of old growth with > 70cm DBH (4.5%) than small-scale private forests (approx. 11 m³ per ha, 3.4%) according to the data of the Germany-wide forest inventory (Kändler et al., 2005). To a greater extent than other factors, this could be related to the high amount of "recent" forests originating from afforestations of former farm lands in private ownership. However, the situation can differ significantly across the region. A case study of deciduous forest stands on ancient woodland sites in the Swabian Alb revealed a significantly higher amount of dead wood in small-scale private forests (22 m³ per ha) compared to state-owned forests (9 m³ per ha) (Schaich and Plieninger, 2013). Growing stock of small-scale private forests was also significantly higher than in state forest in this case study, which was related to a higher tree density as well as to a higher proportion of old growth trees in extensively managed small-scale private forests in the Swabian Alb.



Photograph 5: Old growth beech ('Weidbuche') on a former pasture site in the Swabian Alb region (W. Konold).

Old growth in Baden-Württemberg can actually be found more frequently in remnants of historical forest management systems, in hunting estates, and in protected areas – all of which are also ancient woodlands – rather than in regularly managed forests. Composite forests of coppice and standards in the Upper Rhine Valley as well as overgrown coppices in the Black Forest or the Swabian Alb often host old growth oaks as well as other deciduous tree species (Konold, 2006). Wood pastures and common pasture systems with dispersed trees are also regionally important for the conservation of old growth (see Photograph 5 and the following chapter). Former hunting estates and landscape parks with alley trees could be locally valuable for the protection of old growth trees (Bund Heimat und Umwelt, 2012). Strictly protected forest areas (referred to in Baden-Württemberg as 'Bannwald', as well as in core areas of UNESCO Biosphere Reserves e.g. the Biosphere Reserve Swabian

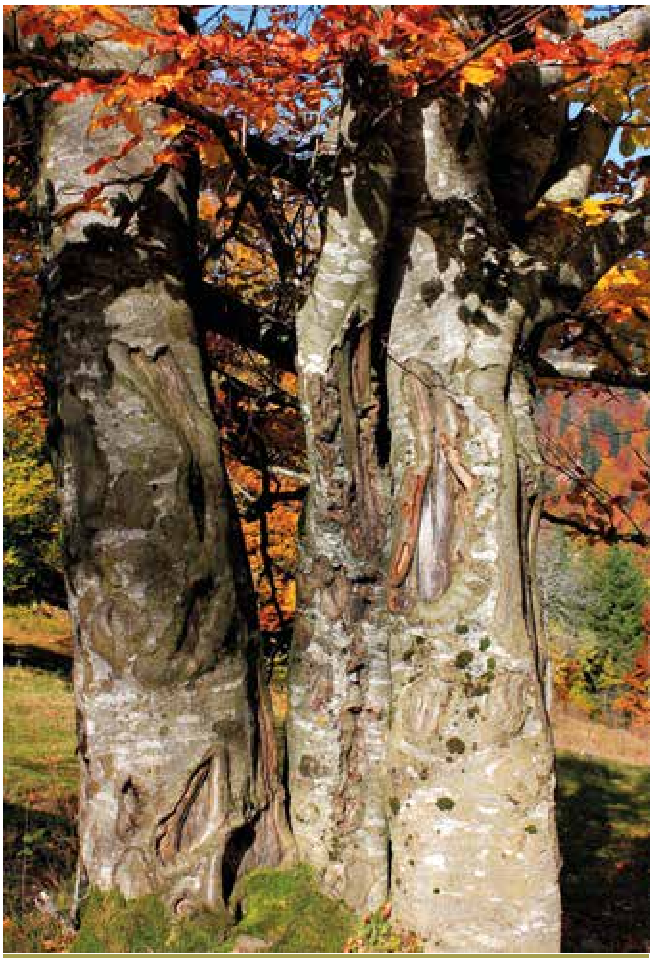
Photograph 6: Strictly protected forest area ('Waldschutzgebiet' or 'Bannwald') in Baden-Württemberg (H. Schaich).

Alb) and forest stands without regular management (referred to in German as 'arB-Wald', e.g. on steep slopes) also add to the stock of old growth and dead wood in the forest landscapes of Baden-Württemberg (Photograph 6). However, with a proportion of 0.6% of the total forest area and a clustered spatial distribution, the contribution of strictly protected forest areas to the enhancement of old growth and dead wood features is still limited in terms of quantity and ecological functionality.

Wood pastures, old growth features and biodiversity in southwestern Germany

In the context of traditional forest uses and their impacts on forest stands, livestock can influence the growth, distribution and diversity of woody species directly through browsing and trampling, as well as by acting as vector for diaspores. Depending on the age of the tree and the intensity of livestock impacts, morphological and physiological changes can occur. If affected woody plants are left to age, pasture-specific and highly irregular shapes can develop (Photograph 7). Adult trees react to browsing on their wooden parts with sap and resin efflux and later by coating the area that has been bitten with extra tissue. These old growth trees, usually equipped with massive crowns, crooked stems and branches, offer multiple structures on their surfaces that serve as habitats for epiphytes, fungi and small animals. They are therefore valuable resources for nature conservation in European forests (Rotherham, 2013).

If livestock grazing is too intensive and combined with wood extraction, it can potentially have a devastating impact. For this reason, forestry laws in southwestern Germany have, since the early 19th century, separated agricultural from forestry use and forbidden non-authorized livestock grazing and herding in forests (Müller, 2005).

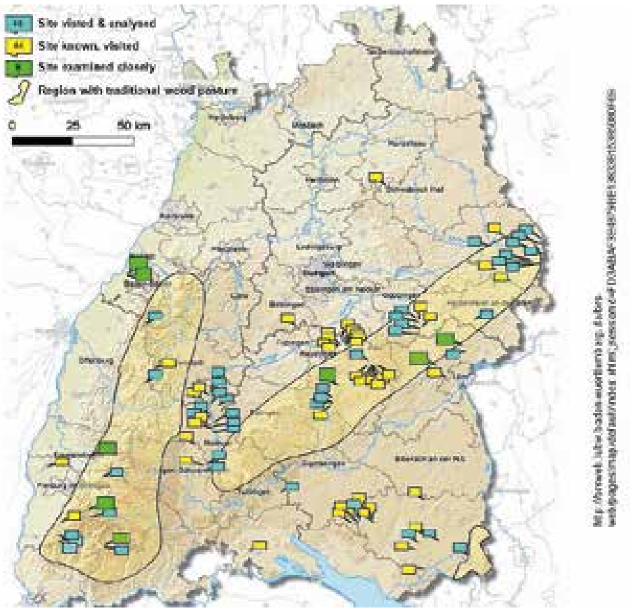


Photograph 7: Livestock impacted, multi-stemmed beech trees in the Black Forest region (W. Konold).

The wood pasture research project: aims, sites and results

Despite the legal prohibition, wood pastures have persisted or have been newly established on small-scale, mostly rural areas in southwestern Germany. A research project on wood pastures aimed to identify currently active pasture woodlands in order to: (a) study land owners' motivations to practice an "illegal" land use as well as their general attitudes in relation to this issue, and (b) to characterize structural and floristic composition of wood pastures compared with adjacent managed forests (Rupp, 2013a). During the three year research project, a total of 100 wood pastures were identified using a pyramid scheme; eight of them were examined in detail with regards to structure and vegetation (Figure 10.1) (Rupp, 2013b). The amount of active wood pastures is surprisingly high in view of their problematic legal status. However, they are usually small with areas varying between 2 and 12 ha. They are situated predominantly in regions with disadvantageous climatic conditions and soil quality, e.g. in the low mountain ranges (see also

Distribution of wood pastures in Baden-Württemberg **Figure 10.1**



Distribution of wood pastures in Baden-Württemberg as identified in the respective research project. The green icons show the closely examined sites and the yellow areas indicate the location of the low-mountain ranges with traditional wood pasturing (on the left hand side: the Black Forest; on the right hand side: the Swabian Alb (Map source: http://brsweb.lubw.baden-wuerttemberg.de, Data source: Rupp 2013a).

Figure 10.1). The livestock used are different breeds of sheep, goats, cattle, and horses, and in one case ibex (Capra ibex). The findings of the study show that this land use was kept alive in some areas in accordance with traditional practice. In other areas, modern nature conservation projects have been the driving force for the reactivation of formerly traditional pasture woodlands.

New wood pastures have often been created in nature conservation areas, in which a former pasture use has been documented. However, in most of the 100 wood pastures identified, old growth trees were cleared during the last two centuries after pasturing was banned and forest areas were managed for timber and fire wood (Härdtle et al., 2004). Most of the trees in the studied wood pastures – predominantly conifers or beech – are roughly 100 years old. However, in some of the wood pastures – with a more or less continuous pasture history – trees that are older than 200 years exist. In interviews, the land owners stated that they would leave the old growth trees because they consider them as something special due to their age, huge dimensions, ecological and cultural value and their unique presence in the landscape. The old growth trees with big crowns were considered to enrich the local scenery and embody a sense of place.

Livestock influences on tree regeneration

Structural analyses were undertaken regarding the influence of livestock on woody species such as trampling and particularly browsing. The affected trees can develop into richly structured adult specimen typical of wood pastures, which are rarely found in other woodland biotopes. Tree layer canopy covers between 10 to 50% of the ground. The understorey layer contains only few trees as many have been browsed by livestock or mechanically thinned out to stimulate herb layer productivity. However, in comparison to adjacent managed forest stands, the wood pastures generally contain more woody species and up to three times more individuals of woody species in the herb as well as in the shrub layer. Due to their semi-open structure, wood pastures receive high quantities of sunlight and therefore offer more habitat niches than closed managed forests. This also allows a wide range of tree species to germinate and to grow up into the tree layer. For example, the tree layer of a reactivated wood pasture on the eastern Swabian Alb contains 15 different tree species with many individuals, whereas the adjacent managed forest hosts only nine species. Noticeable is also the mixture of different light-demanding pioneers (e. g. *Salix caprea, Cerasus avium, Populus tremula, Sorbus aucuparia*) and competitor species (e. g. *Quercus robur, Fagus sylvatica, Ulmus glabra, Tilia platyphyllos*) in wood pasture sites. The spatial distribution of trees in wood pastures is also distinctive: Trees germinate preliminarily in the ecotones between denser and more open areas or at the edges of glades.

In wood pastures, livestock acts more intensely than game species, and nearly all woody species are browsed. In the adjacent managed forest stands, only moderate game browsing was found and this was basically concentrated on deciduous tree species and fir (*Abies alba*). Repeated browsing of apical shoots forces the tree to substitute the loss of stems with the growth of multiple branches that replace the apical shoot. During ongoing browsing on wooded pastures, the netting of branches widens a tree's diameter until the livestock can no longer reach the shoots in the middle. In this so called 'Kuhbusch' stage of tree development (Bergmaier et al., 2010), some shoots in

Photograph 8: A central shoot of *Fagus sylvatica* develops out of a browsed Kuhbusch' stage in the Black Forest (Feldberg region) (M. Rupp).

Photograph 9: Hornbeam (*Carpinus betulus*) in a ring-shaped growth form (diameter: about 3 m) due to browsing on the Swabian Alb (M. Rupp).

the middle of the tree complex that are out of reach of the livestock are able to grow tall (Photograph 8). In the case study wood pastures, such forms were mainly observed in beech (*Fagus sylvatica*), but also in juniper (*Juniperus communis*), lime (*Tilia platyphyllos*) and hornbeam (*Carpinus betulus*). Hornbeam occasionally grows in a ring-shape with diameters of up to 3 m or more, and forms unique trees when aged (Photograph 9).

In wood pastures, tree species that are favored by livestock and are thus less-competitive in regenerating can nevertheless grow up when sheltered by protective species with thorns or prickles (Morgan, 1991). Such trees eventually overgrow the sheltering species and block their sunlight. Interactions were found in wood pastures on the Swabian Alb mainly between *Fraxinus excelsior*, *Acer*- and *Tilia*-species in the shelter of *Rosa*- and *Crataegus*-species, *Prunus spinosa, Juniperus communis* or *Cornus sanguinea.* In the Black Forest wood pastures, dense stands of spruce or holly serve as shelter for *Sorbus aucuparia*.

Old growth features in wood pastures

Trees with DBH from anywhere between 50 cm to more than 130 cm were found in the studied wood pastures. The managed forests adjacent to the wood pasture sites contain forest stands with homogeneous tree ages, dominated by coniferous tree species (spruce and douglas fir), with tree diameters of between 12 and 60 cm and a closed canopy layer. Main factors that influence the tree species composition in the tree layer of the wood pastures are the natural site conditions as well as the respective land use history of the site. Specific interests of the land owners play a central role in determining how sites are managed. On a site in the central Black Forest, huge pines (*Pinus sylvestris*) serve as shelter for the livestock and ash (*Fraxinus excelsior*) provides leaf fodder. In addition, old *Castanea sativa, Cerasus avium* and *Prunus domestica* subsp. *prisca* offer tree crops for livestock and land owners. Land owners of wood pastures in the Swabian Alb mentioned that the naturally growing *Fagus sylvatica* was supplemented by lime (*Tilia* spec.), presumably for fodder and honey production, as well as *Fraxinus excelsior* and *Ulmus glabra* for leaves and timber production.

The comparative study showed that managed forests form mainly closed stands with trees building perpendicular crowns high above the ground, while wood pastures frequently showed park-like structures with trees forming huge elliptical crowns with a browsing line on the underside. The study also revealed the strong presence of zoochorous woody species in the herb and shrub layer in wood pastures, an example of which was found on a site on the eastern Swabian Alb in Figure 10.2. With regards to diaspore distribution, two processes were observed on the project sites: firstly, livestock carries the seeds endogenously and drops them with their excrements, as with *Malus sylvestris* or *Lonicera xylosteum*. Secondly, birds and small mammals are attracted by the semi-open structures in the wood pastures and thereby distribute tree species such as *Cerasus avium, Ilex aquifolium, Crataegus* spec., and *Quercus robur.*

Old pasture trees on the eastern Swabian Alb offer

Figure 10.2

Chory-types of woody species in wood pastures and adjacent managed forests on the Swabian Alb.

Table 10.1

Structures found on the surface of old trees in a wood pasture in a Hutewald on the Swabian Alb (n=475).

Structure	Individuals and percentage [%]
Coating by extra tissue	415 (87,4 %)
Crown hollows	265 (55,8 %)
Mull pockets	86 (18,1 %)
Ulcerations	83 (17,5 %)
Dying parts of bark, branches and stem	195 (41,1 %)

manifold structures on their surfaces (see Table 10.1), such as cracks in the barks, all grades of dying wood, crutches, wounds, hollows and caves, mull pockets, small water basins, ulcerations and overgrowth of former wounds or objects e.g. stones (Photograph 10). Most of these features are dependent on the above mentioned livestock influences during the trees' youth and are rarely found in managed forests. The high surface area of the big crowns of wood pasture trees also offers a realm for epiphyta. In the Upper Rhine Valley, the Swabian Alb and the Black Forest, every old tree we examined was settled by moss and lichens on stems and crowns. On the Alb site, 475 old trees carried mosses, 464 were covered by lichens, 306 bore algae, 50 hosted fungi, and 31 were settled by higher spermatophyta.

Adult pioneer trees – like *Betula pendula, Salix caprea, Populus* spec. and others – appear in higher quantities in wood pastures than in managed forests and can spend their whole life cycle in pasture woodlands without being subject to selective cutting. For instance, in a managed forest stand in the Black Forest, four pioneer tree species were found, whereas in the adjacent wood pasture, ten pioneer tree species were detected in the tree layer. Pioneer trees die earlier than competitor tree species, thereby offering sap and resin as well as softer dead wood, which is essential for many species such as xylobiontic beetles or woodpeckers (Photograph 11). When pioneer trees collapse, they create light islands which attract grazing animals who manage to keep the small glade open for a period of time. Thus, old growth can be seen as an important driver for the spatial dynamics of herbivory: Xylobiontic insects and woodpeckers dig in the wood, various insects feed on the sap, and broken-off rotten branches host small mammals. The examined managed forests offer larger quantities of small to medium sized dead wood (7-50 cm in diameter) than the adjacent wood pasture. However, wood pastures have the potential to enrich forest landscapes with large-sized dead wood when old pasture trees with large crowns decay (Photograph 12).

Photograph 10: Several stems of one *Fagus sylvatica* individual have lifted up a stone. Around the bases of the trunks, different milieus of moisture and light, holes and hollows can be found (M. Rupp).

Photograph 11: Senescent pioneer tree (*Salix caprea*) about to decay completely and used by woodpeckers and insects (M. Rupp).

Photograph 13: Remnant holes of black woodpecker foraging on xylophagous insects in an old growth spruce tree (H. Schaich).

Photograph 12: Toppled oak is left to decay naturally in a wood pasture in the Rhine Valley (M. Rupp).

Conclusion and perspectives

Obviously wood pastures offer a realm for old growth trees, which is rarely present in managed forests. Interviewed land owners, farmers, and nature conservationists appreciate the multiple functions provided by old growth trees to plants, wildlife, farm animals as well as in terms of landscape beauty. The future of wood pastures and old pasture trees is dependent on the existence of farms with extensive livestock management. Their survival is in turn strongly dependent on agricultural and forestry laws and the will of societies to support financially such traditional forest uses. Modern forestry laws with less restriction on the application of wood pasture in nature conservation projects would support the conservation of wood pastures and their respective old growth features. To foster this valuable land use management, initiatives have been developed in Baden-Württemberg to integrate wood pasturing in nature conservation strategies (Schmalfuß and Aldinger, 2012) and to extend funding for land owners via regular agricultural payment programs or payment schemes for nature conservation measures. These initiatives view wood pasture as an important forest use system which unites the conservation of biodiversity, of old livestock breeds as well as of cultural heritage and recreation services.

Old growth as a resource for hollow-nesting birds in the Schönberg region

With a case study in the Schönberg region near Freiburg, we focus on the availability of bigger tree hollows as an indicator of old growth forest components. A range of animal species spanning from insects over small mammals to diverse birds are known to utilise the hollows of bigger trees (Johnsson et al., 1993). As such, the spectrum of the occurring hollow-dwelling species may be used to draw conclusions concerning the ecological status of a forest ecosystem (Wesolowski, 2007). However, exploring the full range of species in question is complex. For this reason the study concentrated on species that are considered to provide adequate insight into processes relevant for the availability of old growth trees: Building hollows for nesting and to use as hides at nighttime, the black woodpecker (Dryocopus martius) can be taken as an indicator in relation to the provisioning of a certain number of bigger tree hollows for so-called secondary hollow users. The black woodpecker is a territorial, insectivorous bird species. Woodpecker territories are known to vary in area between 300 to 600 ha. Territories have to provide a sufficient amount of forage, mainly ants and xylophagous insects and their larvae (Photograph 13) (Gorman, 2011). As such, the presence of the woodpecker is an indicator of the availability of a range of habitat requisites, e.g. old growth and dead wood of different ages and dimensions. Moreover, because of its spatial requirements, this species can serve as an indicator of environmental conditions beyond the spatial extension of single forests stands. Black woodpeckers preferably build their hollows in living trees. Hollows are mostly found in beech (*Fagus sylvatica*) and common pine (*Pinus sylvestris*). In order to avoid predators, the holes are located at a considerable distance from the ground, and they must provide sufficient room for the bird. Thus, in order to be suitable for woodpeckers, forested areas must contain trees of sufficient height and dimensions. Woodpeckers use tree holes for nesting and for hiding during the night and they defend their hollows efficiently against interspecific competitors. Hollows can be in use for years, depending on the inner climatic condition of the tree hole. Moisture and gradual rotting eventually force the woodpecker to abandon a hollow, thereby making it available for other species, e.g. the stock dove (Gorman, 2011).

The stock dove (*Columba oenas*) is a bird species that depends on the presence of bigger hollows and hollow-like structures for breeding. A lack of breeding habitats is assumed to be a main factor restricting the population development of this species. Suitable breeding habitat is characterised by a mosaic of meadows and forest edges, where the birds forage on seeds, fruits and green leaves, as well as forests with a sufficient number of tree hollows (Glutz von Blotzheim and Bauer, 1980; Murton and Westwood, 1974). Ranging distances of the dove vary between 1 to 4 km during the breeding period. As the dove is not capable of creating hollows or niches by itself, it relies on the presence of suitable nesting conditions. Breeding stock doves have been observed in rocks, buildings and even underground in rabbit holes. However, in southwestern Germany, broods of this dove species are almost exclusively sighted in tree hollows that have been built by the black woodpecker (Hölzinger and Mahler, 2001). Given that they are assumed to rank at the lower end of the interspecific competition for tree hollows, the presence of successfully breeding doves may indicate that the availability of hollows is sufficient for the existence of a range of more competitive hollow dwelling species.

Photograph 14: Breeding stock dove detected in a former black woodpecker cave by using an endoscopic camera system (T. Kaphegyi).

The study site

The study site is located at the Schönberg (47° 58’-47° 56’ N, 7° 46’-7° 48’ E) near the city of Freiburg, southwestern Germany, in the foothills between the Black Forest Lower Mountain Range and the Upper Rhine Valley. The absolute altitude is 645 m with an annual average mean temperature of 9 °C. The climate is characterised by relatively high summer temperatures and mild winter conditions. In-situ rock is mainly limestone. At higher elevations, soil conditions are unsuitable for agricultural use. Forest cover consists of deciduous mixed forest, where beech is prevalent. The Schönberg area extends over about 2,400 ha and incorporates forests, pastures, and vine cultivation. About 340 ha are covered by forests, of which 88 ha are beech forest stands older than 100 years (Bogenrieder, 2006).

Study procedure and results

The case study was concentrated on the availability and use of bigger tree hollows with a minimum entrance width of 6 cm in vertical and horizontal dimensions (Johnsson et al., 1993). During the winter season 2007 to 2008, the 88 ha of beech stands of >100 years distributed over the Schönberg area were completely explored for black woodpecker hollows and for hollow-like structures that originate from natural processes such as breaking-off of branches or rotting etc. The leafless period made it possible to search the forest stands efficiently for tree hollows (Stojanovic et al., 2012; Wesolowski, 2001). Trees with hollows were recorded and the diameter, height, and distance of the hollow-structure from the ground were measured. We climbed every tree with potential hollows in order to obtain parameters by which to characterize

Photograph 15: Ring marking of black woodpecker nestlings (C. Harms).

the hollow structure. In this context, we measured the horizontal and vertical diameters of the hollow entrances and of the inner cave, and we assessed climatic conditions and rotting processes within the hollows.

Within the 88 ha of the studied beech stands we found 22 black woodpecker hollows and 90 hollow-like structures in total. During 2008, 2009 and 2010, the use of the hollows by hollow-dwelling animals was explored each spring using an endoscopic camera (Photograph 14). The hollows were used by stock dove, black woodpecker (Photograph 15), green woodpecker (*Picus viridis*), tawny owl (*Strix aluco*), and diverse smaller bird species such as nuthatch (*Sitta europaea*), great tit (*Parus major*), and blue tit (*Parus caeruleus*). In addition to the bird species, different mammals including Eurasian squirrel (*Sciurus vulgaris*), fat dormouse (*Glis glis*), greater mouse-eared bat (*Myotis myotis*), and insects such as the hornet (*Vespa crabro*) inhabited the hollows. On some occasions, successive utilization of the same hollow by different species was identified, however, simultaneous usage was not found. In 2008, about 3% of the available hollow structures and 91% of existing black woodpecker caves were inhabited. In 2009, we found that 8% of the hollow structures were inhabited and 50% of the existing woodpecker caves were in use. The respective proportions in 2010 were 14% for the hollow structures and 64% for black woodpecker hollows. In the Schönberg area, stock doves exclusively bred in hollows formerly built by the black woodpecker. The stock dove preference for black woodpecker hollows has also been confirmed by other research (Kosinski et al., 2010). Other hollow-dwelling species also clearly preferred black woodpecker hollows over other hollow structures ($\chi^2 = 16.432$; df = 1; $p < 0.001$). Some researchers describe dry climate conditions inside the hollow and a maximum of 30 cm depth as important characteristics if the hollow is to be suitable for the stock dove (e.g. Möckel, 1988). In contrast, we found that even very wet conditions and greater depths (e.g. 125 cm) did not prevent the dove from selecting and successfully breeding in hollows.

The population dynamics of the stock dove were monitored from 2008 until 2012 in total. Over the five breeding seasons, the number of breeding pairs in our study area varied between five and nine per season (average: 7.6 a^{-1}). Clutches of the stock dove typically consist of two eggs, and feeding the nestlings with secretion produced in skin folds of the craw allows multiple overlapping breeding per season. Over the five years of the study, the average number of clutches per breeding pair was 1.84 (min.: 1.38; max.: 2.25; SD: 0.35).

Conclusions and discussion: Interspecific relation reveals the importance of old growth forests

The breeding population of the stock dove seems to have been stable during the five year period of the case study. Compared with other research which e.g. identified 1.9 breeding pairs per km^2 in Thuringia (Kühlke, 1985), the density of breeding stock doves ranging from 5 to 9 pairs within the 88 ha of old growth beech stands in the study was considerably high. However, comparing the abundance of breeding pairs, clutches or hollows between different studies is not reasonable in cases where the availability of suitable breeding habitat is not clearly defined for the area where the data in question were collected.

The stock doves in the Schönberg region exclusively used hollows formerly built by black woodpeckers. During the five years of the study, the doves used the same hollows every season, although some hollows provided non-optimal conditions in terms of wet hollow climates and hollow morphology. In a nearby study area, a breeding pair did not abandon the cave even despite a massive woodpecker impact on the individual reproduction success. We observed a black woodpecker destroying the nestlings of nearly all successive clutches in the respective cave during two subsequent seasons. It appears that once stock doves have selected a hollow they adhere to it strongly.

The case study revealed a considerable proportion of non-inhabited hollow-like structures in the old growth beech forests at the Schönberg. This finding may suggest that factors other than the supply of nesting possibilities restrict the population of the stock dove in the area. However, our surveillance did not indicate that predation restricted the dynamics of the dove population nor did the habitat structure suggest that food availability is a minimum requirement for the dove in the case study area. In light of these findings, the case study seems to underline the importance of black woodpecker hollows for a range of forest dwelling species and therefore for forest ecology. This is particularly true since one has to take into account that hollows are used for functions other than breeding, e.g. resting places and night hides, which cannot be readily quantified and therefore may be underestimated in our research. Trees with appropriate dimensions are a prerequisite for black woodpecker hollows. Recent research provides evidence of the black woodpecker preferring beeches affected by heart rot (Zahner et al., 2012). In addition to tree dimensions, the relevance of heart rot for primary hollow dwellers further emphasizes the importance of old growth trees for the ecology and biodiversity of managed forests.

The old growth and dead wood strategy of the federal state Baden-Württemberg

The low amount of old growth and dead wood in state-owned forests together with a growing societal demand with regard to biodiversity conservation (BMU, 2007) led to the development of the old growth and dead wood strategy (ODS – referred to in German as 'Alt- und Totholzkonzept') for state-owned forests in the federal state of Baden-Württemberg (ForstBW, 2010). Given that societal acceptance of forest management is crucial for the legitimacy of the state-forest agency ('ForstBW'), the advancement of the established close-to-nature management approach in regard to old growth and dead wood has been necessary in Baden-Württemberg (MLR, 1993). In addition to this societal development and the basic knowledge that old growth and dead wood resources are lacking, several factors and a special constellation of protagonists and stakeholders opened up a 'window of opportunity' for the implementation of the ODS in Baden-Württemberg's state-owned forests (Waldenspuhl et al., 2011). These included:

- development of a concept of strategic sustainability management for state-owned forests (Waldenspuhl and Hartard, 2010);
- increasing knowledge around the definition of operational threshold values concerning old growth and dead wood for habitat and species conservation (Müller and Bütler, 2010; Schaber-Schoor, 2010);
- a new political constellation of different stakeholders and administrations;
- increased legal requirements regarding the protection of species in forests as well as societal requirements as expressed in the National Strategy on Biological Diversity (BMU, 2007); and
- affirmative guidelines for forestry practice.

Probably the most decisive factor for the establishment of the strategy was the politically motivated restructuring of the competences of federal ministries and administrations in Baden-Württemberg in 2005. Through the consolidation of conservation and forestry administrations into a single department under one directive, the cooperation and the coherence between the respective actions, instruments as well as targets were strengthened.

The legal requirements regarding the protection of forest species have also increased significantly within recent years (Lorho, 2010) and have been a strong driver for the development of the strategy. In 2007, the requirements of the Habitats and Birds directive of the European Union were formulated in an operational guideline for a strict protection system for species and habitats of joint interest of the European Commission (KOM guideline) as well as for the jurisdiction of the European court of justice (Lorho, 2010). According to these new European guidelines and their translation into national and state conservation laws, forest owners had to implement coherent and primarily preventive measures in order to meet European and national legal targets and to guarantee the ecological conditions in the resulting Natura 2000 network of protected areas. The legal proclamation in national and state forest laws that state-owned forests should serve the public welfare in particular (Ruppert-Winkel and Winkel, 2011), was an additional driving force behind the Baden-Württemberg state forest agency's development of a strategy on old growth and dead wood. It also facilitated compliance with the new legal conservation requirements.

The ODS was collectively developed by the forest and nature conservation administrations with the purpose of complying with the new legal regulations on species and habitat protection as well as to guarantee sustainable forest management in the future. Through implementation of the strategy, the preservation and restoration of favourable conditions for species inside and outside the Natura 2000 areas are being accomplished and it is possible to avoid an individual case-by-case review of every forest management and economic measure.

Objectives and strategy development

The forest agency of Baden-Württemberg decided to develop a concept for the conservation of old growth trees and dead wood in 2008, which has implemented in state-owned forests since 2010 (ForstBW, 2010). The major objective was to increase significantly the numbers of old growth trees and the amount of dead wood in managed state forests of Baden-Württemberg. In detail, the old growth and dead wood strategy (ODS) was intended to achieve and to comply with the following objectives and requirements, respectively:

- fulfill the requirements for a favourable preservation status for Annex I forest habitats of the EU Habitats Directive;
- fulfill the conservation requirements of certain Annex

Photograph 16: Old growth beech with a cavitiy and a peculiar proliferation structure (H. Schaich).

II and Annex IV species of the EU Habitats Directive;

- comply with the demands of harvesting safety;
- can be integrated in standard forest management measures; and
- can be re-adjusted according to monitoring results (controlling).

Given that some of the objectives or requirements were partially contradictory, it was necessary for the elaboration of the strategy to engage an interdisciplinary work group consisting of several experts from both the nature conservation and forestry sectors, e.g. experts on species, silviculture, conservation law, harvesting safety, and economics. Experts on species – including birds, beetles, bats, mosses – added their knowledge about species ecology and habitat requirements. Experts on harvesting safety checked which alternative strategy offered the best solutions with regards to forest workers' safety. Forest economists calculated the costs of setting aside old growth and habitat trees and the loss of valuable timber and fire wood resources.

The three components of the strategy

The ODS consists of three basic components of old growth and dead wood conservation:

- Single habitat trees with crucial structures such as large woodpecker holes, aeries or other known essential breeding sites of protected species are marked, reserved from harvesting and protected over the long term.
- Groups of around 15 habitat trees are identified, marked, mapped and set-aside from management and harvesting. As such, they grow large and old, and develop a whole range of old growth features such as crown breaks or wood decay and finally become dead wood. These 'habitat tree groups' are identified in all older stands with an average of one group per three ha.
- Additionally, small forest stands, the so-called forest refugia (in German 'Waldrefugium'), of high protection value are set-aside completely so that they can develop without direct human interference and can decay naturally.

Among the old growth features of highest conservation value were trees with large hollows (Photograph 16), especially when filled with duff, oaks nursing generations of beetle larvae of e.g. *Osmoderma eremit*, and aerie trees as these are often occupied for many years by nesting birds. Trees with these structures should primarily be set-aside from harvesting and should be conserved as single habitat trees.

Although it is often single trees that have a rare structure and are therefore of high value for biodiversity, such trees and their structures are best protected when set-aside together with surrounding trees. For example, beeches with black woodpecker hollows are very rare in managed forests (see chapter above) and should therefore be included in the ODS. When such hollow-trees are left isolated following the harvesting of the surrounding trees, they very often become sunburnt and die quickly, thereby losing their habitat function e.g. as a breeding site for woodpeckers and secondary hollow nesters. If such a hollow tree is integrated into a habitat tree group of beeches, the surrounding trees provide shade and shelter to the hollow tree and act as a buffer against external impacts. Hence, the group of trees will conserve old growth features for a potentially longer period than a single tree. By choosing groups of habitat trees and allowing them to develop naturally until they die and decay, both the number of old growth features and the amount of dead wood increases.

According to the ODS, one group of 10 to 15 trees is chosen per three ha as a habitat tree group. The group is not chosen systematically with regard to spatial distributions but rather according to known breeding sites, existing structures and old growth features as well as concentrations of trees with low timber quality. If possible, forest harvesting requirements are also taken into consideration and habitat tree groups located at a sufficient distance from skid trails and in areas where they are likely to have only few negative impacts on future harvesting operations are designated.

As a third protection component of the ODS, forest refugia with an area of more than one ha are set-aside for strict protection. These are preferably forest stands with old growth trees of huge dimensions on ancient woodland sites with habitat continuity. Other suitable sites are forest stands of a certain age with known habitats of rare, protected, or forest relic species, of low timber quality, low growth rates or unfavourable harvesting conditions. The forest refugia represent small protected forest areas where old growth and dead wood accumulates up to an amount far higher than in the surrounding managed forest stands.

The ODS aims to create a diverse network of old growth and dead wood in managed forests that interconnects functionally with the existing strictly protected forest areas of larger size ('Bannwald', 'arB' stands). Additionally, it is intended to complement and improve the established close-to-nature forest management concept in the state-owned forests of Baden-Württemberg.

Implementation of the concepts in state-owned forests

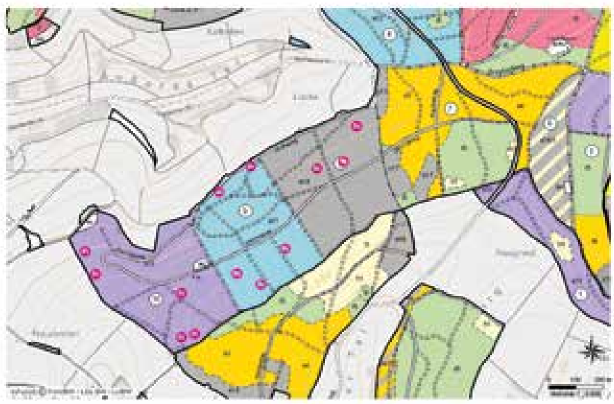
Since 2010, the ODS with its three protection components has been implemented across Baden-Württemberg's state-owned forests, within and outside Special Areas of Conservation (SACs) designated under the EU Habitats directive. Prior to any harvesting operation in forest stands older than 80-100 years or with trees with >50 cm DBH, the district forester who chooses the trees for harvesting is also obliged to designate single habitat trees or groups of habitat trees. Thus, habitat trees and habitat tree groups remain, while the rest of the forest stand slowly reaches harvest maturity and is harvested. Where there are known breeding sites or groups of old growth trees or other trees with valuable structures for biodiversity conservation, they can be designated as habitat tree groups before a harvesting operation and also be selected within forest stands that are younger than 80 years.

As the habitat trees grow older, their stems and crowns become more and more destabilized and are eventually bound to break down. As they are designated and protected within forest stands that continue to be harvested, they become a partly unpredictable source of danger for forest workers. When located next to forest roads or footpaths, they might also become dangerous for forest visitors. The latter risk can be minimized by selecting habitat tree groups located at least a tree length distance from roads, paths and zones with a high visitor frequency.

To improve the long-term protection of the single habitat trees or the habitat tree groups as well as to ensure work safety, the designated trees are permanently marked. A combination of color marking in the field and spatial data detection was field-tested and approved: For the safety of forest workers during future harvesting operations, it is very important that the group of habitat trees is clearly recognizable in the field. Therefore at least all border trees of the group are marked with a white wavy line (Photograph 17). Geographic coordinates of every designated ODS component were measured and recorded in an electronic database, which enabled the production of forest maps that display all habitat tree groups for every operation in the respective forest district (Photograph 18). These maps again add to harvesting safety because possible dangerous zones can be identified prior to harvesting operations. The map also provides an overview of the number and spatial distribution of the single habitat trees and habitat tree groups and the electronic data helps to manage the implementation of the ODS.

The set-aside forest refugia are chosen in the course of the ten-yearly forest management planning process. During forest management planning, the relevant criteria

Photograph 17: Old growth beech within a habitat tree group marked with a wavy white line (N. Schmalfuß).



Photograph 18: Forest map with habitat group trees (red circles).

are best considered in the field. Nature conservation and species experts are involved in the planning process and in the final choice of forest refugia. The set-aside areas are also marked in the field and displayed with their edges of extension within the forest maps.

Training campaign and information on the strategy

Prior to and during the implementation, foresters and forest workers were trained to implement the ODS. This training included topics such as the ecological basis and necessity for the protection of old growth and dead wood, specific knowledge on the ecology and habitat requirements of certain species, the juridical background of species protection, implementation measures and techniques, and the silvicultural operations for the conservation of ODS components in different forest types. The campaign was started with training workshops for more than 200 extension officers who were designated the task of conducting further training within their forest district. However, it became obvious that the foresters and forest workers wanted further support. Thus different types of training and workshops were designed, concentrating on the implementation in different forest types and focusing on specific groups of species.

In addition to the training campaign and the on-going implementation, a range of information material was published. As well as a detailed booklet on the strategy implementation, this included brochures on silvicultural aspects of the implementation in specific forest types, and further information on tree structures, marking and measuring in practice as well as a first report on the status of implementation (Photograph 19).

Status of implementation and perspectives

In the context of the strategic sustainability management of the state-owned forest in Baden-Württemberg, the annual implementation figures for habitat tree groups and forest refugia were published on the state agency's website. This transparency regarding the implementation status of the strategy is very important for the acceptance of all stakeholders and the public.

Until the end of 2011 – two years after the beginning of the ODS implementation – 5,185 habitat tree groups with a total of c. 61,000 individual trees have been designated, marked and documented in the state-owned forests. A habitat tree group comprises a mean of 12 trees. The target value for the designation of habitat tree groups in 2011, which was defined at 3,525 habitat tree groups according to the managed forest area, was thus surpassed by about 50%. This positive development was fostered by a foresighted designation of habitat trees in stands where no management or harvest operation was planned. Moreover, structurally rich or old growth stands

Photograph 19: Available information material for the implementation of the old and dead wood strategy in state-owned forest of Baden-Württemberg.

in a pre-use phase as well as old growth trees over young cultures or young forest stands were very soon designated as habitat tree groups to protect them against clear-away cuttings. At the end of 2011, the implementation of the forest refugia amounted to a total of 642 refugia and a total area of 2,017 ha in the state-owned forests. As planned within the ODS, they are designated within the regular forest planning process. The designated refugia have a mean area of 3.1 ha, which is considerably larger than the defined minimum size for forest refugia of >1.0 ha.

While the implementation of the old growth and dead wood strategy in state-owned forests is making good progress, the desired transfer of the strategies and their principles to municipal and private-owned forests is proceeding slowly. Some forest owners – especially municipalities – implement the concept because of a personal commitment to fostering nature conservation in their forests as well as to comply with demands articulated by stakeholders in the municipalities. So far, no direct financial incentives are provided to private or municipal forest owners for the designation of habitat tree groups or forest refugia even though these would be likely to make compliance with the principles of the strategy more attractive. However, forest owners have been able to credit the implementation of forest refugia as compensatory measures for construction works inside and outside of forests that have had impacts on ecosystems or characteristic landscapes (e.g. construction of new settlements or streets). As habitat banking systems gain importance in the context of the intervention regulation in the federal law for nature conservation and given the increasing importance of publicly financed payment schemes for nature conservation (Schaich and Konold, 2012), the ODS could also serve as a useful tool for safeguarding and developing old growth and dead wood resources in municipal and private forests in the future.

Conclusions

Over recent decades, forests have been increasingly used for timber harvesting as well as for biomass extraction in the federal state of Baden-Württemberg as in almost all regions of Europe (Berger et al., 2013). Economically efficient forest management has consistently strived to avoid successional stages of forest development that are less productive (old growth) or not productive at all (dead wood) and has also sought to abandon traditional supplementary forest uses, e.g. wood pasturing. This leads to a considerable decline particularly of those species that are dependent on old growth and collapsing phases of forest development as well as on light-demanding species in pioneering stages and semi-open forest stands (Bunnell and Houde, 2010; Gustafsson and Perhans, 2010). In 1992, the federal state of Baden-Württemberg introduced a close-to-nature management approach for its state-owned forest area (MLR, 1993), which was successful in enhancing natural regeneration and site-adapted, semi-natural tree composition. However, this did not achieve the necessary increase in old growth and dead wood resources for the conservation of the specific species and habitats and it did not comply with national biodiversity goals and European legislation in southwestern Germany.

In this context, the development and implementation of the old growth and dead wood strategy was a consequent and pragmatic step forward to increase the amount of old growth and dead wood in the overly managed forest landscapes of Baden-Württemberg. Although the strategy has only been implemented for a short time and the ecological effects of this scheme are therefore still largely unclear, the first results of the implementation and the acceptance of the strategy within the forestry and conservation administrations as well as amongst the broader public are quite promising. The old growth and dead wood strategy could therefore serve as a blueprint for other regions in Europe facing the same challenges in forest conservation. However, still deeper insights into the mechanisms of usage and dispersion of resources and requisites provided by old growth forests is crucial in order to refine such strategies and to derive operational targets on quantitative and qualitative parameters for the provisioning of old growth and dead wood resources. According to the current state of knowledge, thresholds for key resources like basic parameters for such strategies refer mostly to the spatial unit of the respective forest stand (e.g. Müller and Bütler, 2010). The availability and distribution of old growth and dead wood features on a landscape level , which is very decisive for the conservation of populations of threatened species that are dependent on these resources, is largely neglected in the standards of such strategies. Here, research must generate more specific knowledge so that a spatially and temporally dynamic network of old growth and dead wood features can be established via operational standards on a landscape level.

Additionally, the case study on wood pastures in southwestern Germany revealed that such traditional, multifunctional land use systems can contribute significantly to enhance structural diversity and especially the amount of old growth resources in forest landscapes. Traditional forest uses, e.g. forest pasturing or composite and coppice forest systems, should therefore be integrated into forest conservation and old growth strategies. Priority should be given to sustaining actively managed, traditional systems and to re-establishing them on sites where such land use systems have been persistent in the past and habitat continuity has not been interrupted for a long time (Schaich and Konold, 2005). Forest laws have to be modified in this sense and state-financed payment programs should be offered to increase the attractiveness for farmers and private forest owners of establishing such traditional land use systems.

With regard to key mechanisms like ecological functionality and habitat connectivity, the implementation of a conservation strategy to enhance old growth and dead wood at a landscape scale in European forests should be taken into account. Herewith, the diverse and regionally varying land ownership structure is an important factor with regards to availability and distribution of old growth elements. In state-owned forests, close-to-nature forestry approaches have to be complemented by the implementation of strategies and management standards to foster old growth and dead wood. In this context, the implementation of sound scientific evaluation as an inherent component of the strategies is required. The development of payment schemes becomes even more important as in times of rising energy prices several countries in Europe are exploring potentials to intensify the harvesting of woody resources for the bioenergy sector from all forest ownership classes and especially from regionally prevalent, old growth-rich, small-scale private forests. Therefore, instruments like payment schemes for old growth and dead wood as well as the implementation of traditional forest land use systems are needed for different forest owners to counter initiatives aimed at extracting more woody resources and to achieve the objectives of the biodiversity strategies for European forests on a landscape scale.

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