Elements of forest maturity to maintain forest biodiversity

In the absence of disturbances, **the dominant trees in the forest reach a phase of senescence and eventually die**. The dead wood that is generated plays a very important role in the carbon cycle and in maintaining forest biodiversity. For this reason, in managed forests **a series of maturity elements linked to age** should also be very important, such as senescent trees, standing dead trees and dead wood in different degrees of decomposition in the soil, which can produce food or habitat for multiple organisms.

The natural dynamics of forests and the role of dead wood

In the absence of disturbances and without logging, forest conditions are controlled by old, dominant trees. As time passes, some of **these trees reach a phase of senescence and die** naturally, leaving the space free where the new regeneration will develop. This process follows internal dynamics linked to phases of degradation and reconstruction, forming a mosaic where large trees alternate in space and time with gaps with young trees in different stages of development.

When these large trees die, the dead wood is eventually incorporated into the soil after a decomposition process which, depending on the environmental conditions, can be short (as in tropical climates, with abundant water and high temperatures) or very long (as happens in cold climates, where low temperatures delay decomposition). In any case, this **dead wood plays a very important role in the carbon cycle** and in maintaining biodiversity, which includes the organisms that participate in the decomposition of wood and those that depend on it as a habitat or source of food. Although this role is difficult to quantify, there is a consensus that **dead wood is one of the most important elements for maintaining biodiversity** (**Figure 1**). Thus, in an area of high conservation value located in the Pyrenees, it has been found that **a large part of this value is linked to dead wood**: a third of the fungi are wood decomposers, there are 465 species of saprophytic coleopterans that are heritage species in many cases (either endemic species or species protected at European level), and approximately a quarter of mammals and a fifth of nesting birds use cavities in dead trunks (**Figure 2**).

The dynamics of natural forests is known mainly from studies of boreal forests in north-central Europe and, especially, North America, while in the Mediterranean region there are few examples of forests that have spent a long time without exploitation or natural disturbances. **In the Mediterranean**, the ancient and intense use of forests, the pressure of agriculture and fires have meant that forests with these elements of maturity are rarely found, since **trees do not normally reach the natural stage of senescence and death**. For this reason, it is absolutely advisable **to preserve a series of maturity elements in managed forests** that guarantee the different processes and allow forest biodiversity to be maintained.

Figure 1. Images of epiphyte typologies: various species of lichens (above), and cormophytes, mosses and saprophytic fungi (below and from left to right). Photos: Lluís Comas/Carles Batlles.

Figure 2. Images of various types of cavities (from left to right): crack, feeding, brood, insects, base and branch on the trunk. Photos: Lluís Comas/Carles Batlles.

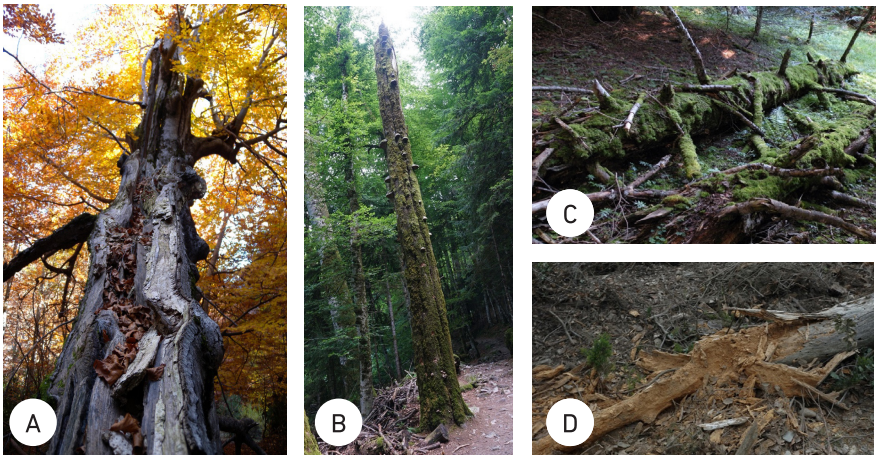

Figure 3. A) Senescent trees, Gresolet (Berguedà). Photo: Lluís Comas/Carles Batlles; **B**) Standing dead tree, photo: Javier Retana; **C**) Barely decomposed dead wood, photo: Lluís Comas/Carles Batlles; **D**) Very decomposed dead wood, photo: Javier Retana.

Elements of forest maturity

The most characteristic **elements of forest maturity** are linked to the age (and to a lesser extent to the size) of the trees, and represent a source of food or habitat for multiple organisms.

- **Mature, senescent and aged trees**. Large (> 40-50 cm in diameter) and old-aged (from 150 years) trees have a **density in the forest that does not exceed 10-15 feet per ha at most** (**Figure 3A**). They are characterised by the **asymmetric shape** of the crown and the presence of **holes** that make it less dense, relatively long trunks **free of low branches** (i.e. forest trees as opposed to trees with open spaces), **long and even thick branches** in the upper part, **deeply wrinkled and old bark**, signs of decay due to a rotten core, and structures with **large and prominent roots**, among others. These trees have many cavities that serve as shelter for insects, birds and mammals; they also have associated complexes of fungi and other organisms different from those of younger trees.

- **Large standing dead trees**. When these older trees die, some remain standing for a long time (**Figure 3B**). Thus, in cold climates, standing dead trees can last as many years as they are alive. These standing dead trees can reach **densities of 30 to 70 feet per ha in North American forests**, but in Spanish forests this density is found in very few stands. Again, these trunks have **multiple cavities** where many species of animals live, mainly insects, and are reservoirs for fungi, mosses and lichens.

- **Dead wood in different degrees of decomposition on the ground**. Dead wood in the soil is perhaps the **most characteristic variable in naturally dynamic forests** compared to managed forests. This wood can be found in all stages of decomposition, from wood from trees that have recently died and is still hard and with a low degree of decomposition, to highly decomposed, soft or spongy wood, which practically dissolves when touched (**Figure 3C, D**). In addition to fallen logs and branches and stumps**, the presence of piles of logs and branches from felling is also important**. Many animals and fungi live in this substrate, which is a reserve of legacies (spores, seeds, insect eggs) that will help regeneration after disturbances, and is also an important reservoir of water.

Species that feed on dead wood versus pest species

Maintaining part of the dead wood in managed forests is one of the most important changes that has been obtained from the knowledge of how the natural dynamics of forests work. Traditionally, **management has systematically (and often exhaustively) removed dead wood from the forest**, considering it an unproductive element and a source of pests. However, we now know that **forest insect pests** (**Figure 4A**) **are necessarily linked to living trees**. These pest species can be classified into primary and secondary pests according to their ability to colonise vigorous trees or weak trees respectively, but they always feed on living tissues. Once the tree dies, these pest species abandon it and leave their place to **saprophytic insects**, (**Figure 4B**), which feed on the tree from the moment it dies until it is reduced to the state of decomposed organic matter. These insects belong to very large families and have thousands of species, all of them incapable of attacking living tissues. Therefore, **dead trees do not present any problem for the forest**. On the contrary, different studies seem to show that in them we find a significant entourage of parasitoids and predators that exert a certain control over forest pest populations.

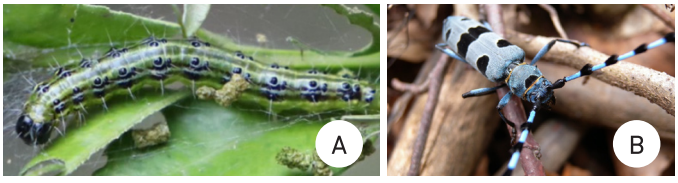

Figure 4. A) Boxwood caterpillar (*Cydalilma perspectalis*), example of a pest. Photo: Emili Bassols, La Garrotxa Volcanic Zone Natural Park. **B**) *Rosalia alpina*, example of saprophytic species. Photo: Lluís Comas/Carles Batlles.