A **comprehensive guide** to assessing maturity and biodiversity in Mediterranean forest stands

A COMPREHENSIVE GUIDE TO ASSESSING MATURITY AND BIODIVERSITY IN MEDITERRANEAN FOREST STANDS

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Cover photo: *centenary oak with partially dead crown and woodpecker breeding cavities (Photo: Lluís Comas).*

CONTENTS

1. INTRODUCTION

It is vital to assess forest habitats for biodiversity and maturity, not least because it is estimated that forests are home to more than two-thirds of the earth's biodiversity (WCFSD 1999). For example, about 30,000 insect species live in European forests (Wermelinger et al. 2013). A significant part of this biodiversity is associated with the more mature stages of the forest (Wirth et al. 2009; Hilmers et al. 2018), highlighting the need for biodiversity assessment at each stage in the life cycle of a forest.

Biological diversity in forests results from evolutionary processes that are millions of years old and are driven by both intrinsic forces (such as competition for resources, mutualism, predator-prey relationships, etc.) and extrinsic factors (disturbances such as fire or extreme weather events) that affect how species interact and evolve. In each specific forest habitat, conserving biological diversity is fundamental for the maintenance of these ecological processes (FAO 2020). The co-evolution of ecological processes, such as those mentioned above, increases ecosystem complexity, leading to more species, matter, energy and interactions in a cyclical progression (Holling 1992). These forest dynamics peak in the later stages, with greater complexity and, consequently, greater biological diversity (Kuusinen and Siitonen, 1998; Redecker et al. 2001; Jacobs et al. 2007; Avila-Cabadilla et al. 2009; de la Peña-Cuéllar et al. 2012; Hilmers et al. 2018). The presence over time of forests with every phase of the forest dynamics cycle leads to a rich heterogeneity, producing a highly biodiverse landscape. On a smaller scale, the greatest biological diversity is found in mature and senescent stands, with taxa that are specific to this stage and not earlier ones. These include species that are not widely dispersed (including endemic species), and which are highly vulnerable to man-made disturbances. Most of the forest species known to be endangered are found in mature stands. A lack of such stands makes the biodiversity associated with these stages very scarce (EUROPARC-Spain 2020a). One of the obvious reasons is that mature and senescent stands contain a greater amount and diversity of resources, structures (vegetation-based micro- and meso-habitats) and micro-climates, facilitating the coexistence of multiple species, increasing the number of niches and reducing the risk of local extinction (Schowalter 1995; Ferris and Humphrey 1999; Stein and Kreft 2015). These factors, together with all the species that interact with each other and with the non-organic features of the environment, are key to forest biodiversity. The greater diversity of species and complexity of ecological structures and processes in the later stages of the forest dynamics cycle makes the ecosystem more stable and resilient to disturbance, while strengthening the resilience of adjacent forest areas with less biodiversity (Bauhus et al. 2017; Gustafsson et al. 2019).

The main way to assess the biodiversity of a forest at stand scale is by exhaustively sampling taxonomic groups, known as bioindicators, that are sensitive to changes in the ecosystem and which, as a whole, are indicative of changes in the global biodiversity of the habitat. However, taxonomic inventories are time-consuming and costly, and require specialist experts. Many studies have documented the links between the occurrence and abundance of particular structural attributes and the abundance and richness of different taxonomic groups (Lindenmayer and Franklin 2002; Bauhus et al. 2009; Gao et al. 2015; Hilmers et al. 2018; Larrieu et al. 2019), which are in turn linked to forest maturity (e.g., Wirth et al. 2009). Another way, therefore, to assess biodiversity is through the use of proxy indicators that are easier to monitor in the field, by identifying the plant and physical habitat structures on which taxonomic groups depend (e.g., Lindenmayer et al. 2000 and 2006).

Indirectly assessing key features is a valid approach and provides a good approximation to biodiversity at the stand scale. However, to date, it has not been possible to identify a complete list of key attributes or features that are fully valid for all taxonomic groups and all forest habitats. Gao et al. (2015) and Larrieu et al. (2019), in two notable and relatively recent studies, found significant relationships between structural elements and certain taxonomic groups, particularly saproxylic beetles, followed by soil beetles, aphyllophorous fungi and mosses. The study by Larrieu et al. (2019) did not find significant relationships with major taxonomic groups such as birds or bats. This may be for various reasons. Complex interactions may affect different taxonomic groups on different time and spatial scales, with very diverse structural and habitat-related factors and a wide range of species and habitat types (e.g. tree microhabitats, deadwood, flowering plants in clearings, water bodies). Consequently, they are not suitable indicators to assess certain taxa at the forest plot scale (Larrieu et al. 2014). However, many studies point out the close correlation between a richness and abundance of forest birds (passerines and woodpeckers in particular) and structural elements at the stand scale (a dozen hectares upwards), reflecting the size of passerine nesting territories (Camprodon 2013). Bats respond better over a larger area, as their hunting ranges are much more extensive. One of the most limiting factors for tree-dwelling bats is the availability of roosts (Russo et al. 2004; Napal et al. 2009), and they have a fairly close correlation to increasing forest maturity (Camprodon et al. 2010). Bats often, however, visit nearby or distant open spaces to feed (Fenton 1989; Schniztler and Kalko 2001).

Figure 1. *In Mediterranean forests woodpeckers excavate their nests in decaying and dead standing trees of diameter class 20 upwards. In the image, a finished cavity and a recently started cavity made by a great spotted woodpecker (photo: Jordi Bas).*

It is important to note that an abundance of all the key features in a stand does not necessarily mean greater biodiversity for all taxonomic groups. It just ensures that the conditions are suitable for hosting the species. A certain species may not be present, despite favourable habitat conditions, for many reasons related to the time scale or location. In terms of time scale, this may be because the habitat conditions may be right, but a species with a low dispersal ability may take time to reach the habitat, or may never arrive. With regard to location, the stand in question may have no or only limited routes connecting it to other stands where the species is present (the island effect). For example, rare species of saproxylic beetles and other invertebrates with a low dispersal ability may be absent in a stand where deadwood has been generated to encourage them, because previous conditions did not favour them and the nearest populations are too far away from the stand. Certain habitats can also be very ephemeral and not very abundant, which makes it difficult to maintain stable populations of certain species, and these are hard to detect because they are only present temporarily.

In order to have an idea of the real biodiversity, it is essential, therefore, to periodically monitor certain taxonomic groups. But which should be measured? Ideally, we should track taxonomic or functional groups with the highest bioindicator value, i.e. which are easy to sample, sensitive to ecosystem change factors, and representative of what may be happening to other groups (Rosenvald and Löhmus 2008; Lindenmayer et al. 2012; Wermelinger et al. 2013). Many taxonomic groups complement each other, so several must be monitored at the same time to gain a more complete picture of the real biodiversity. One of the best groups, due to their short life cycle and high taxonomic diversity (the greatest in the forest), is insects. They are essential to many ecosystem processes and functions, sensitive to changes in their environment at the stand scale, and they react quickly, so they are considered good indicators of overall biodiversity and forest conservation status, meeting many of the requirements defined for bioindicators (Wermelinger et al. 2013). Ants (*Formicidae*), moths (*Heterocera*) and butterflies (*Rhopalocera*), parasitoid wasps (*Terebrantia*), hover flies (*Syrphidae*) and beetles (*Coleoptera*), most notably the saproxylic species, are among the best indicators of a forest's state of conservation. Saproxylic beetles account for between a fifth and a third of a forest's arthropod population (Grove 2002; Stokland 2004). Many insects are relatively easy to assess using standardised methods. Measurements are reliable due to the insects' abundance, covering a wide range of life histories, habitat requirements and functional groups with important roles in forest ecosystems (Ferris and Humphrey 1999; Maleque et al. 2006).

Another approach is the indirect assessment of certain key features, where there is clear evidence that said features are closely correlated with the presence of certain communities of organisms. For example, deadwood is closely correlated with saproxylic organisms. The most diversified saproxylic organisms are fungi feeding on decaying wood (30% of saproxylic organisms), followed by beetles (20%) (Speight 1989; Stokland 2004; Stokland et al. 2012). A stand can also have the capacity to host, for example, forest birds, because there are large trees and a heterogeneous structure. However, if it does not contain deadwood or specific tree microhabitats, then typical forest species such as saproxylic invertebrates and fungi will not be present. Finally, there are species with very particular habitat requirements. Certain disturbances or dynamics must occur to create the conditions they need to exist (for example, beetles associated with fires), but there must also be nearby populations so the species can move in from the source area by dispersal.

Figure 2. *Large lying deadwood in different stages of decomposition (photo: Lluís Comas).*

Finally, since there is a close link between high biological diversity and forest maturity, it is possible to define a series of attributes associated with these processes. These attributes are the result of cyclical forest dynamics that act over hundreds of years, allowing natural processes to take place over time, provided no major natural or man-made disturbances occur. In short, the key factors associated with increased forest biodiversity and maturity at the stand scale are:

- *The spatial heterogeneity* of the forest: the presence of different types of habitats within the forest, such as small open areas exposed to the sun alongside shady, damper areas, a mix of soil types, lithology, topography and altitudinal gradients, providing a greater number of ecological niches occupied by a wide variety of species.

- *The diversity of plant species*. The presence of different species of trees, shrubs and herbaceous plants provides a varied food pyramid and alternative resources for animals and fungi.

- *The structural complexity of the forest*. The presence of trees of different sizes and ages, as well as fallen trunks and other structural elements, creates microhabitats and refuges for insects and other invertebrates, birds, bats, epiphytes such as mosses and lichens, etc.

- *The abundance of deadwood*, of any size, lying or standing, and different stages of decay. Thousands of saproxylic species depend on this resource, in many cases exclusively. The historical scarcity of this resource in most forests has made many of these species rare, and a significant number are endangered.

- *Species interaction*. Interactions between organisms over time and in space, and the functions they perform, such as pollination, seed dispersal, predation, mutualism, competition and symbiosis are essential to maintain the diversity, health and productivity of the forest ecosystem.

For more information on these attributes and processes, see the *Guide to recommendations and technical measures to improve the biodiversity of Mediterranean forests*.

Figure 3. *The spatial heterogeneity of the forest may also reflect the diversity of soil characteristics, lithology and/or topography (photo: Lluís Comas).*

2. PURPOSE OF THE GUIDE

The main purpose of this guide is to present a methodology for diagnosing **maturity and biodiversity hosting potential at stand scale** using direct and indirect indicators for Mediterranean forest habitats. This guide defines and explains the indicators used, the thresholds for assessing them and the common field methodology used to carry out said diagnosis.

It is important to clarify that this methodology is not used to assess the conservation status of a habitat, because it does not measure the area of distribution or the surface occupied by the habitat, or the pressures and threats affecting it, or the communities of species it hosts. The proposed methodology can, however, be used for a stand-scale assessment of conservation status in terms of structure and function; see the *Guide to recommendations and technical measures to improve the biodiversity of Mediterranean forests* for further information on the system for assessing the conservation status of a habitat.

3. BIODIVERSITY AND MATURITY ASSESSMENT SYSTEM

This common guide details two well-established methodologies with a high degree of consensus that are used to simultaneously assess forest biodiversity and maturity. These are the **Index of Biodiversity Potential (IBP)** and the **RedBosques Maturity Index**. The IBP was designed and tested to assess a stand's capacity to host forest taxa (animals, plants and fungi), based on structural and context indicators (Gonin et al. 2012). The RedBosques methodology was developed as part of the Life-RedBosques project (EUROPARC-Spain, 2020b) based on work carried out by Rossi and Vallauri (2013). The index evaluates the forest's naturalness, i.e. its maturity, human footprint and spatial integrity. Although both indices use similar indicators for structure and composition, there are some differences in how they are defined and in the sampling methodology. This guide describes the indicators used in both methodologies, their differences, and proposes a common field sampling methodology for performing a combined assessment.

Although not the subject of this guide, it is also important to assess the effect of forest management and other disturbances on taxa of special conservation interest (endemic species, locally rare taxa, etc., listed as under threat in official catalogues of endangered flora and fauna). Rare or endangered species that are particularly sensitive to changes caused or influenced by forest management may be prioritised (Jonsson and Siitonen 2013). It is important, therefore to establish monitoring methodologies based on scientific consensus. In some cases, standard or near-standard monitoring techniques may be used for a few endangered species that are sensitive to forest management. In others, it will be necessary to adapt monitoring methodologies that are already applied in one way or another by different researchers or research groups. These assessments should coincide, with regard to methodology and the locations selected, with those performed for the indirect indicators detailed above.

Figure 4. *Girdling a stone pine as part of a LIFE BIORGEST natural dynamics measure (photo: Jordi Camprodon).*

4. STAND INDICATORS

The two indices have different aims: while the RedBosques Maturity Index (RB) measures a stand's maturity, the IBP indirectly estimates the potential taxonomic diversity that a stand can host. As the sampling methods and how the variables are measured in the field vary slightly, the similarities and differences for each indicator are detailed in the section below. The reason for choosing each indicator is also explained. Table 1 summarises all the indicators and Table 2 sets out the thresholds for classifying a stand in terms of potential biodiversity or maturity.

The science behind the proposed indicators, for example, for microhabitats of living trees (Siitonen 2001; Larrieu et al. 2018; Stokland et al. 2012) or for large deadwood (Jonsson and Siitonen 2013; Kriebitzsch et al. 2013; Lachat et al. 2013), gives this combined assessment system a distinct advantage when evaluating both maturity and potential diversity.

TABLE 1

Comparison of the main methodological differences and sampling constraints for the two assessment protocols: RB (Redbosques Maturity Index), IBP (Biodiversity Potential Index). The sampling details and constraints for each protocol are contained in the guide.

Indicator	Protocol	Scale	Description	Differences / Constraints
Native tree species	RB	Stand	Number of different native tree species at any stage of development present in the stand	Live h≥50 cm
	IBP	Stand	Factor A. Number of genera other than native tree species at any stage of development, dead or live, present in an area of 1 hectare.	Dead or live h≥50 cm
Basal area	RB	Plot	Average basal area (m^2/ha) (live trees of DBH > 17.5 cm) of all the plots	DBH≥17.5 cm
	IBP		Not used in assessment	

Indicator	Protocol	Scale	Description	Differences / Constraints
Vertical strata	RB	Plot	Number of strata. There are four strata of equal height (tree species only, at any stage of development) + 1 emergent stratum	CC ≥ 20%
	IBP	Stand	Factor B. Number of strata - 1 herbaceous and semi-woody stratum - 4 woody strata: very low (< 1.5 m); low (1.5-5 m); intermediate (5-15 m) and tall (≥ 15 m)	CC ≥ 20%
Diametric classes	RB	Stand	Number of DCs other than native tree species present in all the plots sampled	DBH≥17.5 cm
	IBP		Not used in assessment	
Large and very large trees	RB	Plot	Number of exceptional live trees per hectare. A tree is considered exceptional if its DBH in cm is at least three times the dominant height in m (H_o) of the species in the stand.	DBH≥3 x H_o
	IBP	Plot	Factor E. Number of live trees per hectare of: - Large trees (LT) - Very large trees (VLT)	- LT (37.5<DBH<57.5 cm) - VLT (DBH≥57.5 cm) or (DBH≥37.5 cm)*
Medium and large deadwood	RB	Stand	Volume of standing or lying deadwood of any tree species Percentage (%) of total deadwood volume (standing and lying) in relation to the volume of live trees	DBH≥17.5 cm
	IBP	Plot	Factor C. Standing dead trees or snags of Medium Deadwood (MDW) and/or Large Deadwood (LDW) at least 1 metre high (H) Factor D. Lying medium deadwood (MDW) and/or large deadwood (LDW) of at least 1 meter length (L)	- H o L≥1 m - MDW (17.5<DBH<27.5 cm) - LDW (DBH>27.5 cm) or (DBH≥17.5 cm)*

* For site quality type C (poor) or for species in slow-growing genera *(Arbutus, Acer, Pyrus, Sorbus, etc.)*

Indicator	Protocol	Scale	Description	Differences / Constraints
Tree microhabitats (TreM)	RB	Stand	Number of different types of TreM detected in all the plots (based on the 10 proposed types). A TreM type counts if there are at least two per hectare.	
	IBP	Stand	Factor F. Number of live trees with TreMs per hectare (record and classify, based on the 15 types, all trees with TreMs observed up to a maximum of two trees/ha × TreM group).	
Flower-rich open areas	RB		Not used in assessment	
	IBP	Plot	Factor G. Percentage (%) of surface area containing open spaces with flowering vegetation	
Dynamic	RB	Stand	Each phase of the forest dynamics cycle is represented in the stand (1. Gap, 2. Regeneration, 3. Occupation, 4. Exclusion, 5. Maturation, 6. Senescence)	
	IBP		Not used in assessment	
Forest continuity over time	RB	Stand	Proportion of forest in 1956 (%)	Base year 1956
	IBP	Stand	Factor H. Areas with trees in the 1945 orthophoto and no signs of previous or subsequent agricultural use or soil disturbance as a consequence of reforestation.	Base year 1945

4.1. NATIVE TREE SPECIES (IBP-RB)

Definition
Number of native tree species or genera present in the stand at any stage of development (including regeneration).

Sampling (differences and constraints)
RB. All living tree species in the stand over 50 cm tall are recorded. The score recorded is the **number of distinct species** found in the entire stand.

IBP (Factor A). All living tree species in the stand over 50 cm tall are recorded **by genus**. The score recorded for the stand is the number of different **living or dead** genera found in one hectare. If two hectares are sampled, the average score is used.

Rationale
Maturity. In a natural forest it is likely that multiple tree species will coexist (Gosselin et al. 2004), generally five or more, except in certain forests such as beech or subalpine forests (which have few species) or in riparian forests, which conversely tend to have a higher variety of species. In forests in more mature phases, more shade-tolerant companion species tend to appear in the vegetation strata below the canopy. Depending on the height of the species that occupy the upper canopy, these will gradually merge into the canopy. This slow merging process occurs as older trees lose part of their crown, leaving small gaps that allow more light to enter, which is exploited by these species. There is a correlation between species richness and the structural diversity associated with maturity, as this diversity allows light to enter the forest at different levels, giving tolerant, slow-growing species the opportunity to find sufficient light to grow up to the dominant stratum. Examples are species like *Sorbus torminalis, S. domestica, Acer opalus, A. campestre, Tilia cordata, Prunus avium, Taxus baccata*, etc.

Biodiversity potential. The biodiversity of the communities associated with trees depends on key structural differences such as how palatable their leaves are to insects and other phytophagous organisms, the hardness of the wood, the roughness and stability of the bark, the ability to form microhabitats, etc. While they vary from those in another genus in these and other ways, tree species within a genus will have similar associated communities of fauna and flora species. For example, the physicochemical characteristics of the bark of the genus *Pinus* determines the associated moss community, which is different from those associated, for example, with the genus *Acer* (Casas et al. 2003). Such specialisation is rare at tree species level. The epiphytic moss community tends to be richer and more diverse in most broad-leaved trees because of their stable bark, which does not flake off like *pinaceae*. In addition, rough bark, e.g., oak rather than beech, is better (Belinchón et al. 2011), because it provides a more stable substrate and retains moisture better. Epiphytic lichen and moss richness in managed temperate forests depends on maintaining tree species diversity in mixed stands; pine forests, in particular, need a proportion of large deciduous trees, mainly oaks (Király et al. 2013).

The same is true for birds. For example, most European tit species display a preference for either conifers or for broad-leaved trees, but do not distinguish between specific tree species (Camprodon 2013). Meanwhile, woodpeckers prefer stands containing certain broad-leaved species, such as black or white poplars, as the soft wood is easier to excavate for nesting (Camprodon et al. 2007). Insects have a very diverse range of preferred habitats. For example, the larvae of certain Lepidoptera, Hymenoptera and beetles feed on genus-level nourishing plants, including arboreal genera. To give just one example, some caterpillars in the Sphingidae family feed happily on linden (*Tilia ssp.*), poplar (*Populus ssp.*), willow (*Salix ssp.*) or pines (*Pinus ssp.*) (Chinery 2005). With deadwood, the associated saproxylic beetle community varies according to whether the deadwood is from coniferous or broad-leaved species. For example, the darkling beetle *Diaperis boleti* lays its larvae on polypore fungi on broad-leaved trees, especially birch (Albouy and Richard 2019). Tree mix is a key variable for a diversified saproxylic beetle community in Mediterranean forests (Parisi et al. 2020). The unique saproxylic beetle communities in Mediterranean forests depend on a mix of old oaks as companion trees in the dominant stratum and/or as a component of the woody understory, trees that will eventually form part of the dominant stratum in pine forests (Buse et al. 2010).

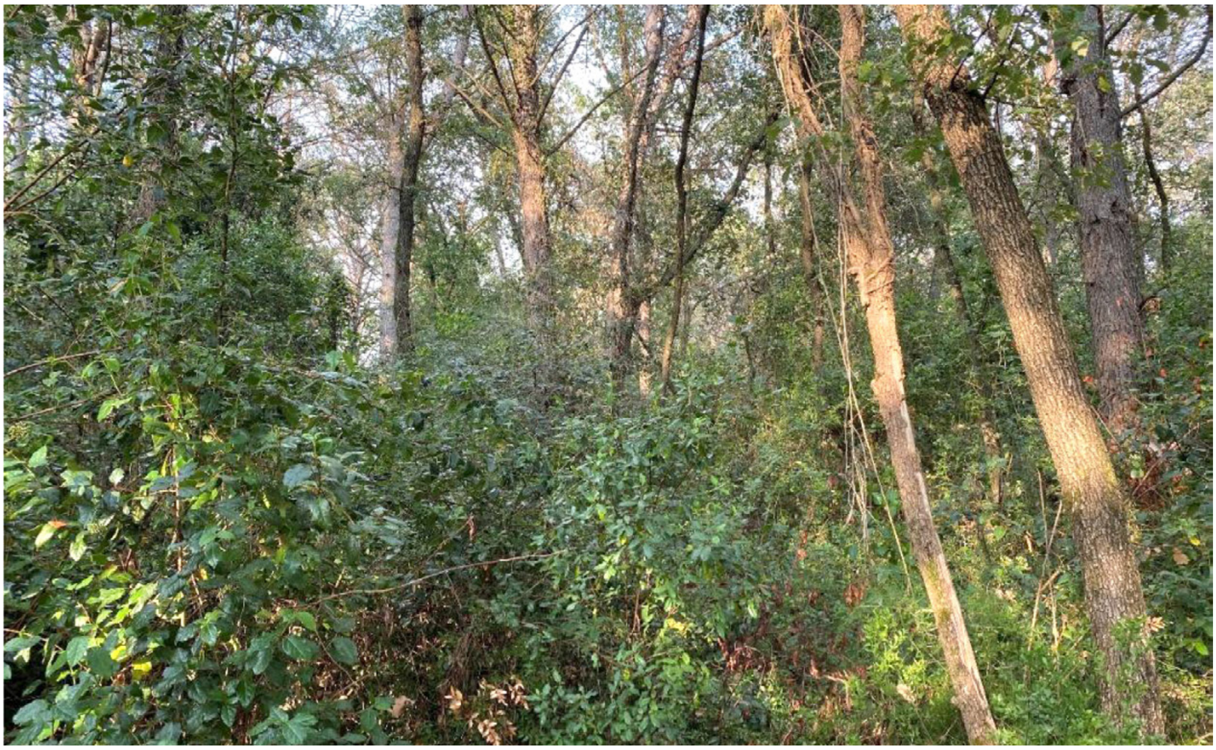

Figure 5. *Mediterranean mixed broad-leaved forest (oak and holm oak) and Aleppo pine (photo: Jordi Camprodon).*

4.2. BASAL AREA (RB)

Definition
The average basal area (in m^2/ha) of all plots calculated taking all living trees of at least 17.5 cm DBH (trunk diameter measured at 1.30 cm above ground).

Sampling (differences and constraints)
RB. All live trees at least 17.5 cm in diameter in each plot are sampled. The score recorded for the stand is the mean basal area of all sampled plots.

IBP. Not sampled.

Rationale
Maturity. Basal area is a classic forest indicator, describing both the density of trees and their average size, providing a very simple indication of the standing biomass. The basal area of natural temperate forests is generally between 20 and 50 m^2/ha. It may be somewhat lower in more extreme climates, in the Mediterranean due to lack of water, or in subalpine zones due to low temperatures. It can also be lower where the site quality is poor (stony or very thin soils). In managed forests with long rotation periods the score may be higher. The basal area will increase and decrease depending on the phase in the forest dynamics cycle, with lower values in the initial (gap, regeneration and occupation) and final phases (senescence phase) and higher values in the intermediate phases (exclusion and maturation).

Figure 6. *The basal area of a stand increases significantly with the presence of mature trees (photo: Lluís Comas)*

4.3. VERTICAL STRUCTURE (IBP-RB)

Definition

The number of vertical strata of vegetation present in each plot and at any stage of development, provided that in a given stratum the fraction of covered area is at least 20%.

Sampling (differences and constraints)

RB. Four vertical strata of equal height occupied by tree species are identified, plus a stratum of trees emerging from the dominant canopy. The score recorded for the stand is the mean of the strata of the sampled plots.

IBP (Factor B). The following strata are identified: herbaceous and semi-woody vegetation, very low (< 1.5 m), low (1.5-5 m), intermediate (5-15 m) and high (≥ 15 m) woody vegetation.

Rationale.

Maturity. A natural, mature forest will generally be irregular with various vertical strata (Bauhus et al. 2009). In the more mature stages of a forest, new strata tend to emerge because other, shade-tolerant, species appear and occupy the vegetation strata below the canopy. Examples are species such as *Sorbus torminalis, Sorbus domestica, Acer opalus, A. pseudoplatanus, Tilia cordata, Prunus avium, Taxus baccata*. Over time, the canopies of the older trees in the upper canopy become less dense, allowing more light to enter the lower strata. Clearings may also open up in the canopy due to the death of a dominant tree, allowing the growth of new cohorts of the dominant species, or, depending on the size of the clearing, of other more heliophilous species. In other cases, a new stratum may emerge, corresponding to relatively isolated stands that outgrow the dominant tree cover (e.g., mixed forests with scattered and isolated Aleppo pines above a lower dominant holm oak forest). In these cases, it is highly improbable that the emergent stratum will be maintained in the future because these are transitional forests where the pioneer species remain in place. It is most likely that these isolated trees will disappear with time and this emerging stratum will disappear.

Biodiversity potential. Vertical stratification is an important aspect when measuring the biodiversity and functioning of a forest. A multi-stratified forest is vertically heterogeneous, favouring a wide range of species thanks to a diversity of microenvironments (with different sunlight, temperature and humidity levels) that can contain numerous taxonomic groups (lichens, mosses, aphyllophorous fungi, birds, etc.). For example, there is a long-understood association between passerines and vertical vegetation structure (MacArthur and MacArthur 1961; Wilson 1974; Wiens 1989) and the structural elements associated with maturity, especially for cavity-nesting birds that feed in the trunks and thick branches of living, decaying trees and deadwood (Avery and Leslie 1990; Newton, 1994; Winkler et al. 1995; Harrap and Quinn 1996; Thingstad, 1997; Camprodon et al. 2008).

Diversity increases if there is a well-developed bush and liana stratum, with the greatest diversity in holm oak and cork oak forests with cover of over 50% (Camprodon 2013). Similarly, a wealth of understory species leads to a greater diversity of insects associated with certain nutritious plants and of saprophytic, parasitic and mycorrhizal fungi. A dense shrub and liana stratum also provides shelter for ungulates and carnivores. Dense forests with vertical continuity between the tree crowns, shrubs and lianas are not, however, conducive for flying bats (Guixé and Camprodon 2018).

The tallest trees (more than 15 m), especially those that stand above those around them, facilitate the nesting of numerous birds of prey. For example, in holm oak forests in the of La Garrotxa (Catalonia), different species of birds preferentially selected nesting sites in accordance with the height and cover of the tree or shrub strata (Camprodon 2013). The strata may be simplified as a result of forestry measures, including clearing or thinning to remove weak, unpromising trees.

Figure 6. *Coastal holm oak understory. The Mediterranean forest usually has a very abundant and diverse understory (photo: Lluís Comas).*

4.4. DIAMETER CLASSES (RB)

Definition
This indicator is included in the RB protocol only and refers to the number of diameter classes (DC) of native tree species present in all the sampled plots.

Sampling (differences and constraints)
RB. The number of DC are counted from class 20, i.e. all living trees with DBH > 17.5 cm. The score recorded for the stand is the number of distinct DCs from all sampled plots.

IBP. Not sampled.

Rationale
Maturity. In a forest the number of diameter classes is an indicator of maturity because, in the absence of severe disturbances, the score increases with time. A natural forest usually has an irregular structure both in terms of diameters and tree height. A young forest typically has a smaller number of diameter classes with a reverse J-shaped, bimodal or fairly even distribution. As the forest grows, the number of classes increases and the proportion of trees in the smaller classes decreases. In the mature stages, the fall of a large tree allows a new cohort to grow, so the forest will contain trees in the smallest classes at the same time as very large trees.

Figure 7. *Holm oak forest with various diameter classes in a LIFE BIORGEST stand (photo: Jordi Camprodon).*

4.5. MEDIUM AND LARGE DEADWOOD (IBP-RB)

Definition

The quantity of standing or lying medium or large deadwood of any tree species found in the plot. The sampling method, indicators and constraints vary widely between the two protocols.

Sampling (differences and constraints)

RB. The sampling threshold for deadwood is an DBH of at least 17.5 cm. No distinction is made between lying or standing deadwood. Two indicators are calculated from the data for each plot: the volume of deadwood (standing and lying) and the proportion of deadwood in relation to the volume of living trees. For both indicators the stand scale score is the maximum value for all sampled plots.

IBP. Separate counts are made of the number of dead standing trees or snags of at least 1 meter in height (Factor C) or the number of lying dead trees (Factor D) of at least 1 meter in length (L). Medium deadwood (MDW) has an DBH of between 17.5 and 27.5 cm and large deadwood (LDW) has an DBH of at least 27.5 cm. Exceptionally, where the site quality is poor (type C) or for slow-growing species (genera Arbutus, Acer, Pyrus, Sorbus, etc.), deadwood with an DBH of 17.5 cm is treated as LDW.

Rationale

Maturity. Large deadwood is common in mature forests. It is an indicator of maturity because it is most abundant in the later phases of the forest dynamics cycle as larger trees, at the limit of their longevity, die off. The volume of deadwood as a proportion of the volume of living trees is greatest in the senescence phase. The proportion of deadwood in mature forests generally varies between 10% and 30% of the total wood volume.

Deadwood, whether standing or lying, forms the basis of a complex food web allowing a succession of ecological processes, improving the integrity of the habitat and its natural balance, making it more resilient to external disturbances. Deadwood, whatever its size, has important ecological functions. It can reduce erosion and is key for soil development, it stores carbon and water, it is an important source of energy and nutrients, helps certain species to germinate, and is an important habitat for decomposers and heterotrophic organisms (Harmon et al. 1986; Franklin et al. 1997; Kirby and Drake 1993; Samuelsson et al. 1994; McMinn and Crossley 1996; McComb and Lindenmayer 1999). The incorporation of deadwood in the decomposition process ensures nutrients are retained and recycled. The organic matter that is incorporated into the soil also enhances its physicochemical properties, its cation exchange capacity, its structure and water retention capacity (Lachat et al. 2013). In a context of climate change, protecting soil from disturbance allows all these properties to be maintained and even improved, albeit very slowly. Any earth movement, apart from increasing the risk of erosion if the vegetation cover is sparse, increases the amount of organic matter available to decomposer organisms (fungi and bacteria), accelerating decomposition (Wirth et al. 2009).

Biodiversity potential. Large deadwood is a key habitat for a wide range of saproxylic species (Müller and Bütler 2010). The dominant groups of saproxylic species include fungi, mosses, lichens, insects, amphibians, birds and mammals. A total of 25% of forest species depend on deadwood (Bobiec et al. 2005; Stokland et al. 2012), including three key ecological guilds for forest biodiversity: xylophages, detritivores and cavity-dwelling species. Of all the substrates, deadwood is probably the most critical for biodiversity (Jonsson and Siitonen 2013) and is essential for a wide variety of saproxylic flora and fauna. De Zan et al. (2014) found large numbers of birds and saproxylic beetles when the amount of large deadwood in beech forests is greater. Each organism plays a specific role in the decomposition cycle of deadwood. Fungi successively break down sugars, cellulose and finally lignin. Some insects eat wood directly (xylophages), others consume fungi on deadwood, others are predators of the former, etc. The most tolerant species can survive on a few stumps and thick, dead branches. More demanding species, or those with limited mobility, will only survive if there are substantial amounts of the required type of deadwood and it is well distributed throughout the stand (Bobiec et al. 2005). For example, large-diameter deadwood is essential for the survival of certain beetle species whose larvae develop over several years or which only colonise dead trees after 4 or 5 years (Dajoz 1974).

After fungi, saproxylic beetles are the most biodiverse species associated with deadwood. Oaks, for example, have been estimated to host about 900 species (Gilg 2012). A stand's capacity to host saproxylic beetles depends not only on the quantity of deadwood, but above all on its quality, a key aspect already mentioned above. For example, some species, such as *Nacerdes carniolica*, occupy large conifer trunks; others, such as Prionychus ater, favour cavities in old Mediterranean broad-leaved trees; the larval phase of species such as *Triplax lacordairii* takes place in saproxylic fungi on Mediterranean broad-leaves and conifers, while other species, like *Pytho depressus*, live under the bark of conifers, etc. (EUROPARC-Spain, 2020b). In general, broad-leaved species are richer in saproxylic beetles than conifers.

Deadwood, especially large deadwood, also influences the diversity of epiphytic organisms: lichens and mosses (Hofmeister et al. 2015). For example, several species of epiphytic mosses have been identified as characteristic of advanced stages of wood decay in conditions where there are high levels of ambient humidity throughout much of the year (Crites and Dale 1998), for example, *Buxbaumia viridis, B. aphylla and Calypogeia suecica*. More mature forests contain greater volumes of deadwood, so the more naturalised the forest is, the richer in epiphytic mosses and lichens it will be (Boch et al. 2013; Ardelean et al. 2015). Epiphytes in turn form specific microhabitats for invertebrates. Their slow growth and limited dispersal capacity mean communities recover slowly from episodes of disturbance.

To maximise a stand's capacity to host the saproxylic and epixylic species associated with deadwood, the deadwood must be abundant, come from the different tree species or genera potentially present in the stand, and be of different sizes and degrees of decomposition (Kriebitzsch et al. 2013). The quantity of deadwood, although important, is less important than the quality and diversity. The key factor is the mix of lying and standing deadwood at different stages of decomposition (Lassauce et al. 2011). Standing dead trees are important as a source of nesting holes for woodpeckers and of autogenically occurring cavities (raised bark, cracks in the trunk). These provide essential nesting places for other fauna, especially when there are not enough cavities in living trees, leading to a succession of users that swap cavities at different times and locations . Decayed or dead standing trees provide microhabitats for a different range of saproxylic fungi and invertebrates species to those that prefer lying deadwood, according to the level of decomposition and humidity. The saproxylic community is the basis of a complex food chain. Invertebrates and birds prey on it and they in turn, together with parasites and parasitoids, regulate the populations of saproxylic organisms. For example, saproxylic fungi also form a microhabitat for saproxylic beetles that in their larval stage feed on the fruiting bodies of the fungi.

In conclusion, a greater variety of deadwood in significant quantities leads to a greater diversity of species, a more complex network of interactions and more stable populations (Lachat et al. 2013). Deadwood volumes of between 15 and 20 m3/ha in managed coniferous and deciduous forests have been found to be insufficient to support saproxylic communities, and a target volume of between 20 and 50 m^3/ha is considered appropriate (Müller and Bütler 2010). Bouget et al (2013) set a limit of about 50 m^3/ha for oak forests, as the number of common species increases more slowly when the volume of deadwood is more than 46 m^3/ha.

Figure 9. *Standing dead tree, retaining large branches. Saproxylic beetle exit holes and woodpecker feeding cavities can be seen (photo: Lluís Comas).*

4.6. LARGE AND VERY LARGE TREES (IBP-RB)

Definition
The number of large or very large live trees present.

Sampling (differences and constraints)
RB. A tree is considered exceptional (very large) if its DBH (in cm) is greater than three times the dominant height (Ho, in m) of the species in the plot. Example, if Ho = 15 m, ED = 42.5 cm. The score, at stand scale, is the mean number of exceptional trees per hectare for all sample plots.

IBP (Factor E). A tree is considered large (LT) if the DBH is between 37.5 and 57.5 cm and very large (VLT) if its DBH is at least 57.5 cm. Exceptionally, where the site quality is poor (type C) or for slow-growing species (genera *Arbutus, Acer, Pyrus, Sorbus*, etc..), trees with an DBH of 37.5 cm are treated as VLT.

Rationale
Maturity. Exceptional diameter trees rarely occur in managed forests unless they are managed using retention methodologies. The number of exceptional trees is a good indicator of maturity because a tree takes a long time to reach an exceptional diameter, well over 100 years, usually more than 200 years. Live trees with exceptional diameters make some of the most important contributions to the vertical structure of the forest. They are a vital refuge and resource for a rich variety of species and for ensuring communities continue to function. Exceptional trees are usually those that have reached the maximum possible height for a given site quality. When these trees reach the limit of their longevity, they generally crown. At this point the crown can only extend horizontally and the tree continues to grow only in diameter. As they age, these wide-crowned trees leave many open spaces that allow light to enter. This can be exploited by a wide range of shade-tolerant species that will occupy the intermediate strata.

Biodiversity potential. As a tree ages, it is more likely that a range of microhabitats will form, creating potential substrates for a great diversity of associated species, many of them saproxylic. Parts of the trunk and crown of large trees may die off, especially if they go into decline, but the living part can continue to grow for decades. While this is happening, new microhabitats will appear while others disappear. This dynamic results in a continuum of microhabitats (some very ephemeral) being maintained over very long- time scales, allowing for stable populations of a wide range of species, including rare or endangered species.

Lichens and mosses are generally slow-growing organisms, some of them very slow, so species richness and abundance depend on maintaining the trees that serve as substrate and on stable microclimate conditions. For example, *Lobaria pulmonaria* is a particularly slow-growing, large-thallus lichen that acts as a bioindicator of long-term stable conditions in forests (Gilg 2005).

Figure 10. *Large holm oaks (Quercus ilex) are scarce, but older examples can become very large (photo: Lluís Comas).*

4.7. TREE MICROHABITATS (IBP-RB)

Definition

The number of tree microhabitats (TreM) observed in living trees.

Sampling (differences and constraints)

RB. The **number of distinct TreMs from the 10 possible groups** (Annex A.1 and A.2). A TreM counts if it is found at least twice in the plots surveyed. If a tree has two different types of TreM, both are recorded; if the same tree has several TreMs of the same type, they are counted only once.

IBP (Factor F). The **number of live trees with TreM per hectare, provided they are different.** Each tree where a TreM is observed is classified under one of 15 possible groups (Annex A.1). All trees with TreMs observed are counted up to a maximum of two trees per hectare per TreM group. If a tree has different TreMs, each TreM type is counted; if the tree has several TreMs of the same type, it is counted once.

Rationale

Maturity. The abundance and diversity of tree microhabitats increase significantly with tree diameter and bark thickness and thus normally with tree age (Bütler and Lachat 2009; Vuidot et al. 2011; Larrieu and Cabanettes 2012; Ellis 2012; Nascimbene et al. 2013; Larrieu et al. 2019). Consequently, live trees with TreM are usually large old trees associated with maturity. These trees contain different TreM that significantly increase the biodiversity of a wide range of species (especially invertebrates) and, therefore, promote and maintain certain ecological processes that are not usually found in harvested forests. The presence of these trees, especially if there is a high diversity of TreM, facilitates the resilience and natural balance of the habitat by establishing a complex network of interactions between species.

Biodiversity potential. Living trees, especially older ones, contain TreM that are essential for the survival of many species (Larrieu and Gonin 2008; Emberger et al. 2013). It is estimated that 20-40% of forest species in temperate and northern forests depend on or benefit from trees with TreM (Bobiec et al. 2005; Stokland et al. 2012; Bauhus et al. 2019), most notably saproxylic beetles (Parisi et al. 2019), many of which are among the most endangered organisms in European temperate forest ecosystems (Bütler et al. 2013). In a natural forest, the diversity and number of trees with TreM is high, well above 10 trees/ha.

Cavities are the microhabitats that host the most species of both invertebrates and vertebrates. Those with more organic matter (Ranius 2002) are the richest in invertebrates, but a wide range of physical attributes (volume, size of the opening, orientation, relative location and diameter of the tree) are also influential (Quinto et al. 2014), as is the biochemical content of the substrates (Micó et al. 2015). Large burls can also host other microhabitats that influence invertebrate diversity (Ramilo 2018).

In the IBP, mosses and lichens are classified as microhabitats. Ecologically, they help conserve the ambient humidity of wood and soil, which is beneficial for other species such as fungi, vascular plants and invertebrates. They also provide habitats for small invertebrates such as nematodes and molluscs.

Saproxylic hover fly larvae are aquatic or semi-aquatic and are closely associated with forest microhabitats such as hollows in living trees. These contain temporary or semi-permanent accumulations of water (dendrotelmata), with warmer temperatures and more comfortable humidity levels than open air pools (Micó et al. 2013).

Figure 11. The 10 types of TreM listed in the Redbosques protocol and associated taxonomic groups (modified from Kraus et al. 2016, photos: Lluís Comas).

4.8. FOREST DYNAMICS (RB)

Definition
The presence of each of the six phases of the forest dynamics cycle throughout the entire stand. The forest dynamics cycle comprise six phases: 1. Gap, 2. Regeneration, 3. Occupation, 4. Exclusion, 5. Maturation, 6. Senescence.

Sampling (differences and constraints)
RB. The presence of a phase is recorded if it occupies an area of at least 200 m^2, with the exception of the regeneration phase which must be at least 100 m2. The score recorded for the stand is the sum of the values assigned to each phase: Clearing=2, Regeneration=1, Occupation=1, Exclusion=1, Maturation=2, Senescence=3.

IBP. Not sampled.

Rationale
Maturity. In the absence of major disturbances, in a forest with natural dynamics, every phase in the cycle will be observable. The structural and

ecological properties typical of mature forests appear gradually over time, resulting from the ecosystem's own dynamics, in a continuous cycle. Provided there are no major disturbances, each generation of the dominant vegetation goes through successive structural stages, from new growth through to the complete renewal of the canopy once all the individuals from the initial generation die off. Different ecological processes take place in the tree ecosystem at each phase of the cycle. The last stages (maturity and senescence) are the most important in terms of forest maturity as they require up to hundreds of years and only happen in the absence of harvesting (timber, firewood, etc.) or disturbances that could affect the forest's structure, function or composition. Bauhus et al. (2009) estimate that in forests managed for timber 10-40% of the cycle does not occur, i.e., they are kept in the early stages of the cycle. The forest dynamics cycle and the description of each phase can be consulted in the *Guide to recommendations and technical measures to improve the biodiversity of Mediterranean forests*.

Figure 12. *Large gap in a holm oak stand with regeneration of yew, holm oak and different herbaceous species (photo: Jordi Camprodon).*

4.9. FLOWER-RICH OPEN AREAS (IBP)

Definition
The proportion of the surface area containing open spaces with flowering vegetation (forest clearings, sparse forest, open spaces on the forest edge). These may be permanent or temporary, natural or due to management.

Sampling (differences and constraints)
RB. Not sampled.

IBP (Factor G). Record the surface area of clearings and areas of sparse vegetation in the entire stand. A score is given if the area occupied by flowering species is between 1% and 5%.

Rationale
Biodiversity potential. Forest biodiversity requires a certain proportion, albeit low, of open spaces that allow flowering species to be relatively permanently present (monotones, corridors, etc.). Many forest and saproxylic fauna need open, sunny spaces at some point in their life cycle. Some species of saproxylic beetles feed on flower nectar and pollen in their adult phase, for example. At the stand scale, there needs to be enough open space to maintain viable populations of these species, but not so much that it would compromise the light, temperature and humidity levels that typify dense forests, thereby endangering the associated biodiversity. Clearings are maintained by the grazing action of domestic and/or wild ungulates or by skeletal soils and turf-like plants that prevent the widespread regrowth of trees.

Note, this must not be confused with the clearing phase of the forest dynamics cycle, which results from the death of one or more trees at the limit of their longevity, opening a gap. In this case the space can be swiftly reoccupied, especially if the area is small, to prevent flowering species from taking hold. The clearing may close up due to the lateral growth of the surrounding tree canopy or when a new cohort of trees grows up to quickly occupy the entire space.

Figure 13. *Open spaces at the forest edge, colonised by flowering species (photo: Lluís Comas).*

5. CONTEXT INDICATORS

5.1. FOREST CONTINUITY (IBP-RB)

Definition
The stand is deemed to be old-growth forest if the land was already tree covered in the mid-20th century and its use has not changed since then.

Sampling (differences and constraints)
RB. The percentage of the land covered by trees in 1956-57 per the orthophotomap developed from aerial photographs taken in that year is recorded. This indicator is used to assess the historical human footprint together with the agricultural, livestock and forestry uses of the land.

IBP (Factor H). The stand is deemed to be old-growth forest if the land was tree-covered per the 1945 orthophoto and there are no indications of previous or subsequent agricultural use or soil disturbance as a result of reforestation. For this indicator, it is also necessary to note in the field if there are evident signs of forest discontinuity (walls, terraces) in all or part of the stand, or evidence of forest continuity in stands that were clear of trees in 1945 (very old trees retained on the edges of former pastures, rocky areas where trees were not removed, etc.); soil disturbance throughout entire reforested areas (subsoiling, ploughing between rows, the uprooting of vines); any historical document that indicates the age of the forest.

Rationale
Maturity. The maturity of a forest is closely linked to the state of the soil. Forest soil takes many decades to mature and stabilise, characterised by high concentrations of organic matter, cation exchange capacity, fertility, and fully developed organic horizons. Any disturbance of old soil has immediate consequences, and it can take many decades, even centuries, to recover.

Biodiversity potential. Traces of former agricultural uses or livestock grazing in a forest remain for a long time (decades or even centuries). The impact can be very visible and linger in the soil for many years. Some species of flora grow only in forests and require forest continuity because they have a very low dispersal ability or a low capacity to adapt to non-forest soils. These species will not, therefore, be found in forests that are recently established on pastures or abandoned agricultural land (Hermy et al. 1999; Hermy and Verheyen 2007; Dupouey et al. 2002a and 2002b).

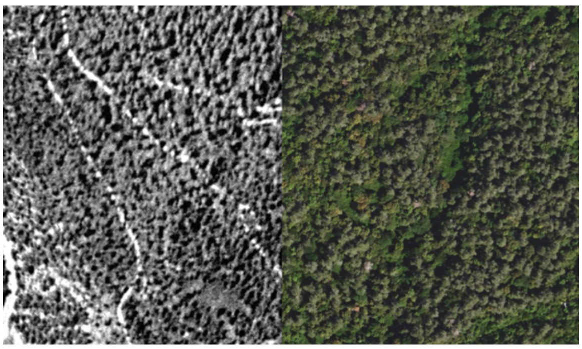

Figure 14. *Forest continuity over more than 60 years. Comparison between aerial photographs taken in 1956 and the present day (source: Institut Cartogràfic i Geològic de Catalunya).*

5.2. AQUATIC HABITATS (IBP)

Definition
The presence of different types of aquatic habitat in the stand or its immediate vicinity.

Sampling (differences and constraints)
RB. Not sampled.

IBP (Factor I). The presence of the different types listed in Annex A.3 is recorded (the maximum score is given if there are at least two different types).

Rationale
Biodiversity potential. Freshwater aquatic systems are among the most biodiverse inland ecosystems (Dudgeon et al. 2006; Maes 2010; IUCN 2022). It has been estimated that, despite their small surface area, they contain 10% of known organisms (WWF 2020). They interconnect and interact ecologically with the ecosystems through which they flow and act as biological connectors (Gregory et al. 1991; Wohl 2016). Their physical, chemical and biological characteristics depend on and reflect the state of the ecosystems of the basin as a whole. At the stand scale, shade cast by riparian trees regulates water temperature, limiting algal blooms, slowing decomposition processes and eutrophication, and maintaining suitable environmental conditions for fish. The submerged roots of alders and willows provide shelter for aquatic invertebrates and fish.

Forest biodiversity benefits from the presence of aquatic habitats in or near the forest: streams, rivers, bogs, wetlands, ponds, lakes, etc., are vital for several typical forest plant species, such as alders and willows. Forest bats drink and hunt by flying over bodies of water. Many species of birds, mammals and reptiles are semi-aquatic, such as the white-footed shrew, the desman, the water rat, the otter and the water snake. Duck and heron roost and breed in the trunks or crowns of riverside trees. Amphibians need watercourses and watering holes for breeding, and dense forest near the streams where they live to keep these habitats sufficiently cool and damp (especially in summer).

Figure 15. *Breeding colony of herons with up to 300 nests in an alder grove on the banks of the Ter River (photo: Jordi Bas).*

5.3. ROCKY HABITATS (IBP)

Definition
The presence of different types of rocky habitat in the stand or its immediate vicinity.

Sampling (thresholds and particularities)
RB. Not sampled.

IBP (Factor J). The presence of the different types listed in Annex A.4 is recorded (the maximum score is given if there are at least two different types), provided the habitat accounts for a total area of at least 20 m^2/ha.

Rationale
Biodiversity potential. Forest biodiversity may depend in part on rocky habitats and many species are only found if this habitat exists. Rocky habitats have distinctive characteristics (type of rock, humidity, thermal inertia) providing a suitable environment for different forest species: a substrate for mosses and lichens, micro-soils for rock-growing flora, shade, shelter, refuge for numerous reptiles, amphibians or arthropods. Examples include fissures in dry walls that provide shelter for small mammals (shrews and rodents) and microfissures occupied by arthropods.

Figure 16. *Top: dry wall in a Life BIORGEST holm oak stand. Bottom: rocky outcrop in the shade of a holm oak forest with Ramonda myconi (photos: Jordi Camprodon).*

6. THRESHOLDS

The threshold values used to score each indicator are set out separately for each protocol (Table 2). Four levels are proposed for each indicator: very low, low, medium and high. The threshold values in the table are based on those detailed in the original Redbosques (EUROPARC-Spain 2020b) and IBP (Baiges et al. 2022) protocols.

The general rationale for basing the threshold values on structural and compositional indicators rather than on specific bioindicator species is that it is much easier than assessing the habitat requirements of each individual species. This "coarse-filter" approach (sensu Hunter et al. 1988) meets the requirements of most forest species, but risks overlooking the needs of some specific species. An alternative "fine-filter" approach involves including a more selectively chosen set of target species to ensure there are viable populations of said species. This gives forestry managers greater reassurance that the management measures implemented will be successful (Jonsson and Siitonen, 2013).

The threshold applied for structural attributes depends, to a large extent, on the taxonomic group or processes that need to be protected (Bauhus et al. 2009). For example, the density and distribution of deadwood is important for maintaining a stable population of saproxylic insects. The proportion of deadwood at different stages of decomposition, and its distribution and size over time, may also be important for habitat continuity for species with different levels of mobility or different feeding and shelter requirements (Grove 2002; Harmon 2002). In the absence of more detailed information, the solution is to maintain the features and attributes needed to support as many processes as possible at the same time, thereby providing habitats for a wide range of species. This is the philosophy behind the IBP.

However, for most forest ecosystems, our understanding remains quite limited of the quantity of these features needed, and how they need to be distributed in space and time, in order to meet certain biodiversity and maturity targets (Bauhus et al. 2009; Müller and Bütler 2010; Bouget et al. 2013; Larrieu et al. 2019). This is especially true in the Mediterranean region. In terms of maturity, there are no mature reference forests in the Mediterranean region against which comparisons can be made.

With regard to biodiversity, for which there is a lot of information, what, for example, is the threshold requirement for deadwood to ensure saproxylic biodiversity is high and stable? The answer usually depends on the conservation goal or on the species, but to ensure success, as much as possible to ensure its continuity in a sustainable manner in space and time (Jonsson and Siitonen 2013). Since habitat requirements differ between species and for different types of forest, it is almost impossible to identify deadwood thresholds that guarantee the survival of the entire saproxylic species community (Ranius and Jonsson 2007; Jonsson and Siitonen 2013). In addition, maintaining stable communities of saproxylic species depends not only on the quantity but also on the quality of the structural features, and on a forest structure that ensures these features are also maintained over time. As a general rule, for species with restricted ecological niches (specialists) and/or species with limited dispersal ability, the extinction threshold will be more critical (Müller and Bütler 2010).

Figure 17. *Girdled and felled deadwood to encourage biodiversity (photos: Jordi Camprodon).*

In practice, it is easier to define a threshold when it is based on a single species. However, it is much more useful to try and set thresholds at the community level. It makes sense, therefore, to consider as many species as possible when setting habitat thresholds for maintaining the entire community of species that depend on, for example, deadwood (Lachat et al. 2013; Bouget et al. 2013). Müller and Bütler (2010) conducted a literature review based on 37 thresholds for deadwood. For most of the species or species groups surveyed, the study found a peak of between 20-30 m^3/ha in boreal coniferous forests, 30-40 m^3/ha for mixed-montane forests and 30-50 m^3/ha for Central European temperate forests. According to the authors, these quantities are sufficient to maintain most populations of saproxylic species. However, some very demanding species require a much higher amount of deadwood. It is advisable, therefore, to establish forestry reserves where a natural dynamic is maintained that generates sufficient quantities of deadwood to support these species (Jonsson and Siitonen 2013), with different types of deadwood distributed throughout the forest's ecosystems to ensure connectivity between populations (Jonsson et al. 2005).

Table 2 shows the proposed thresholds for both protocols: IBP thresholds for biodiversity carrying capacity indicators and RB thresholds for stand maturity indicators. Naturally, these proposed thresholds may be modified as empirical data is built up on i) the relationship between these indicators and how each taxonomic group responds in terms of richness and ii) the maturity scores that can be obtained for each indicator in mature stands treated as reference stands.

For IBP (Baiges et al. 2022), the minimum values would be those considered compatible with multifunctional forest management: IBP thresholds corresponding to a score of 5 for each indicator. It should be noted that, although achieving this minimum score can produce a qualitative leap in terms of biodiversity for many taxonomic groups, it does not mean that increasing, for example, the quantity of wood would further boost the associated biodiversity.

For maturity, the proposed thresholds are those associated with natural dynamics, i.e., greater maturity and a smaller human footprint, in short, management aimed at conserving the functions and processes inherent to natural dynamics and the associated biodiversity. The thresholds for each indicator are based on a range established in the original protocol (EUROPARC-Spain. 2020b), with scores from 0 to 10, as part of the work of the LIFE Redbosques project. For example, the range of values established for the volume of deadwood for holm oak forests is between 5 and 25 m^3/ha, i.e., below 5 m^3/ha the indicator score for deadwood is very low, above 25 m3/ha the score is high, while between 5 and 25 the score is low to medium. A forest is considered mature if the reference scores are "high".

TABLE 2

Threshold values for each indicator for biodiversity hosting capacity and maturity. For details of each variable see Table 1.

		Threshold score			
		Very low	**Low**	**Medium**	**High**
IBP Capacity to host biodiversity **RB Maturity**		**0** **0-0.9**	**1** **1.0-3.9**	**2** **4.0-6.9**	**5** **7.0-10**
Indicator	**Variable**				
Native tree species	IBP No. of genera (living or dead individuals) RB No. of live species	0-1 <3	2 3-4	3-4 5-6	≥5 ≥7
Basal area	RB Basal area (living trees) (m^2/ha)	<21.5	21.5-25.9	26-30.4	≥30.5
Diameter classes	RB No. of classes(1)	<6 <8 <6	6-8 8-10 6-8	9-11 11-13 9-11	≥11 ≥13 ≥11
Vertical structure	IBP No. of vegetation strata RB No. of tree strata	<2 <2.2	2 2.2-2.8	3-4 2.9-3.4	5 ≥3.4
Large and very large trees	IBP Number of large (LT) and very large (VLT) trees (trees/ha)	<1 VLT and LT	<1 VLT and ≥1 LT	1-4 VLT	≥5 VLT
	RB Number of exceptional trees (trees/ha)(1)	<14 <23 <33	14-25.9 23-31.9 33-41.9	26-37.9 32-40.9 42-50.9	≥38 ≥41 ≥51
Medium and large deadwood	IBP Number off medium (MDW) and large (LDW) standing (trees/ha)	<1 LDW and MDW	<1 LDW and ≥1 MDW	1-2 LDW	≥3 LDW
	IBP Number of medium (MDW) and large (LDW) lying (pieces/ha)	<1 LDW and MDW	< LDW and ≥1 MDW	1-2 LDW	≥3 LDW
	RB Number standing and lying (m^3/ha)(1)	<14 <14 <8	14-25.9 14-25.9 8-16.9	26-37.9 26-37.9 17-25.9	≥38 ≥38 ≥26
	RB Deadwood as % of live trees	<7.5	7.5-14.9	15-22.4	≥22.5
Tree microhabitats	IBP Trees with TreMs (tree/ha) RB Number of different types	<2 <4	2 4	3-7 5-6	≥8 ≥7
Flower-rich open areas	IBP Proportion of area without tree cover (%)	0	0	<1 o >5	1-5
Dynamic	RB Silvogenetic phases (phase)(2)	1 and/or 2	3 and/or 4	5 and 6	All
Forest continuity over time	IBP Forest before 1945 (value) RB Proportion of forest before 1956 (%)	0 0-10	0 11-25	2 26-75	5 ≥76

(1) *Score by habitat and by order: 42.84 - Aleppo pine forests (*Pinus halepensis*); 41.7&1 - Oak groves (*Quercus humilis*) or hybrids; 45.3 - Evergreen oak and holm oak (*Quercus ilex or Q. rotundifolia*)*

(2) *Six distinct silvogenetic phases are observed: 1) gap, 2) regeneration, 3) occupation, 4) exclusion, 5) maturity and 6) senescence*

7. COMBINED ASSESSMENT FIELD PROTOCOL

No changes are made to the respective field protocols for each assessment system, except for some details described in this section. For assessing maturity, the plot sampling system should be used (LIFE Redbosques 2018). This document describes the field methodology and the calculations to be made to obtain the maturity indicators. In order for the IBP assessment to be compatible with the Redbosques assessment, the IBP sampling system for plots must also be followed *(https://cpf.gencat.cat/ca/cpf_03_linies_actuacio/cpf_transferencia_coneixement/Index-Biodiversitat-Potencial/documents-i-publicacions-relacionades-amb-libp/Fitxes_i_protocol_IBP/).*

The field table used for the combined sampling methodology is contained in Annex A.5. The data sheet is divided into two sections. The first is for stand scale data, comprising the sum of the indicators collected at plot scale as well as those collected only at stand scale, such as the IBP context factors (Factors H, I and J) or, for example, the RB indicator for the number of different diameter classes. In the plot section, the size of the plots must be decided in order to determine the number of plots needed to sample the required area.

The area sampled must cover at least one hectare and represent between 15% and 50% of the total area, i.e., for every 6 hectares, approximately, at least one hectare must be sampled. It is highly recommended to carry out the sampling with circular plots, therefore, if plots of 25.2 metres radius are used, five plots are needed, if the plots are of 32.6 m radius, three plots are needed, and so on. It is recommended that no fewer than three plots per stand be used.

For IBP sampling, there is no upper limit for factors C and D (standing and lying deadwood) and factor E (very large trees), even if the threshold for obtaining the maximum score of 5 has been reached. The only upper limit applied is for factor F (TreM), if the threshold value of two trees with the same microhabitat is reached. For the remaining factors, A, H, I and J, the original sampling methodology should be followed.

With this sampling approach, the complete assessment takes more time than that proposed in the original versions of the sampling protocol.

The differences in the sampling approach with respect to the respective original protocols are:

- In each plot, count the number of live trees by diameter class (DC) and species starting at DC 20 (ND>17.5 cm). For DC 20 and DC 25, count only the trees up to the 10 m radius. From DC 30 to DC 55, all trees within the chosen sampling radius (25.2 m if five plots are sampled, 32.6 m if three plots are sampled, etc.) must be counted. From DC 60 onwards, the DBH must be measured and noted. The measurements can be taken with a tree caliper or forestry tape measure.

- Obtain the dominant height (H_0) in each plot and for each species (normally one species, or two if the CCF of the second is at least 30%). H_0 is calculated from the average of the three thickest trees in the plot. This figure, with the number of trees per DC and per species, is used to calculate the volume, including bark, of live trees. This can then be used to obtain the deadwood to live wood ratio.

- For lying deadwood, of all pieces with a diameter of at least 17.5 cm, measure the length up to this diameter and the diameter of the trunk at half this length. For the standing dead trees present in the plot, measure the normal diameter and height of the trunk. This information can be combined with the total number of pieces of lying and standing deadwood to calculate the total deadwood volume.

- For the IBP indicator for live trees with TreM, the number of trees is recorded by TreM type observed, up to a maximum of two trees/ha per TreM group, based on the 15 types listed in Annex A.1 and A.2. If a tree has different TreMs, each TreM type is counted as one tree; if the tree has several TreMs of the same type, it is counted once. For Redbosques, record the number of different TreM detected in all the plots, based on the 10 types detailed in Annex A1 and A.2. A TreM type counts if there are at least two per hectare. If a tree has two different types of microhabitats, it will be recorded twice.

Figure 18. *IBP and RedBosques protocol field sampling (photo: Lluís Comas).*

8. PROTOCOLS FOR DIRECT MONITORING OF BIODIVERSITY AT THE STAND SCALE

This section contains recommendations regarding sampling protocols and the direct monitoring of biodiversity for different taxonomic groups. As noted in the introduction, a given stand may have characteristics that make it more or less suitable for certain species. Nevertheless, the species may or may not be present due to other external and difficult-to-control factors. Directly monitoring biodiversity through standardised sampling methods is the best way to demonstrate that a given action has a direct effect on biodiversity conservation, in short, that there is a cause-effect relationship. In the long term, understanding these relationships can help to determine the best management option in each case and to establish the best thresholds for improving the biodiversity of different taxonomic groups.

8.1. SAPROXYLIC BEETLES

There are twice as many species of saproxylic beetles as in any other vertebrate group, with at least 2,500 Iberian species (Grove 2002). Different ecological or functional guilds can be distinguished according to the substrate where the larvae develop. The guild of xylophagous species, for example, colonises decaying wood in the early stages; these species are able to fragment and partly break down the complex organic molecules in decaying wood (lignin, cellulose and hemicellulose). The most degraded wood, mixed with other organic plant debris, is suitable for saproxylophagous species. When the state of decomposition of the wood is well advanced and it accumulates in the form of humus, saprophagous species appear. One specific functional guild is the xylomycetophages, whose larvae feed on saproxylic basidiomycetes, ascomycetes and microscopic fungi (Stokland et al. 2012) or on vegetation in the different stages of decomposition generated by these fungi or their products (Alexander 2008). As well as these ecological guilds, there are predators specialising in deadwood insects and commensal species.

Saproxylic beetles are probably the ecological and biodiversity indicators that provide the most information on the direct biodiversity of the forest and the functional complexity of the ecosystem (Müller and Bütler 2010; Lassauce et al. 2013). The saproxylic insect community responds rapidly to changes associated with standing or lying deadwood because these species have a short life cycle compared to other taxonomic groups such as birds or bats. It is understood, therefore, that changes in the saproxylic beetle community can be used to make inferences about the entire saproxylic community, making it one of the best bioindicators associated with maturity. It is necessary to collect a representative sample for each stand, bearing in the mind the budget constraints on the field sample design, especially the number of plots per stand. This includes: i) the cost of the traps; ii) time spent on sample collection and preparation; iii) identifying beetles, according to family, genus or species, in order to understand their feeding ecology.

It is advisable to install at least three passive interception traps, one per plot surveyed for indirect indicators. Traps should be installed simultaneously in all stands from the beginning of May to the end of July to coincide with the months of maximum activity of saproxylic beetles in Mediterranean climates. The samples should be collected every 15 days and fixed with 70º alcohol. CROSSTRAP mini flight interception traps from ECONEX are a good choice.

The beetle species from each sample are identified separately. The other arthropods captured can be kept for future studies. A database is constructed for each separate capture, detailing the trap (= plot), stand and sampling date. The finds are classified by saproxylic functional group fields and saproxylic functional guilds. This information can finally be cross-referenced to data on the structure and composition of the plot in live and dead trees, the quantity and diversity of standing and lying deadwood, and the diversity of other taxonomic groups (mosses, birds, etc.).

Figure 19. *Top: BIORGEST plot with passive trap for saproxylic beetles. Bottom:* Cerambyx cerdo*, saproxylic beetle (photos: Jordi Camprodon / Jordi Baucells).*

8.2. BIRDS

The correlation between bird abundance, stand age, canopy cover, vertical stratification of vegetation and density of large trees is well known. This is true for the bird community in general, but in particular for the woodpeckers and passerines that are the secondary occupants of tree cavities (Camprodon 2007). The absence or scarcity of trees of a certain size (greater than 30 cm normal diameter) is critical for some species, such as the black woodpecker or nuthatch in Mediterranean forests (Arriero et al. 2006; Camprodon 2013).

Common forest birds are inventoried using quantitative bird sound recording (Tellería 1986; Bibby et al. 1992), the usual method in forestry habitats, since it is a point census that fits well with forestry and vegetation inventories. This census is valid for birds (passerines, woodpeckers and columbidae), that use song to mark their territory or which make loud noises. The census only fails to detect birds of prey and other large, solitary, wide-ranging and sporadically occurring birds, which would require a specific sampling protocol.

Sampling sites must be located at the centre of the dasometry plots to obtain the combined indicators detailed in this guide. Bird species observed or heard in four concentric bands of 25 m, 50 m, 100 m and greater than 100 m are counted. To ensure the dasometric variables tie in with the maturity and IBP indicators, observations within the 50 m band should be selected for statistical processing. In dense forests such as the those in the Mediterranean this is a limit that can be controlled by the census taker. The recommended listening time is 20 minutes. Shorter periods may omit birds that do not emerge, while longer periods do not provide much additional information and are time-consuming, limiting the number of sampling sites per session.

The census is normally carried out on nesting birds, since this is the most critical time of the year, when birds are especially territorial. In Mediterranean habitats, the recommended census period is from 20 April to 10 June, or later in high mountain environments. Censuses are carried out from half an hour after sunrise until mid-morning, allowing for a maximum of 4-6 sites per day, if travel between sites does not take too long.

To ensure total independence of the sample, we recommend one site per stand of less than 10 ha or several sites separated by a minimum of 400 m, coinciding with the habitat inventories and then calculating the mean per stand. As they have larger territories than passerines, woodpecker numbers tend to be underestimated at listening sites. This also applies to nocturnal birds (woodcock, nightjars, birds of prey). Since these two groups represent valuable biodiversity indicators, additional censuses can be conducted. For example, 10-minute sessions at sites about 500 m apart, supported by playback of recordings of the songs of each species. In March and April (the main breeding season), in the morning for the woodpeckers and during twilight and the first two hours of the night for the nocturnal species. Passive detection methods with automatic recorders are currently being developed. For the moment, this technology is useful for censusing scarce, rare and/or difficult to detect species, for which specific identifiers have to be developed.

The most commonly used metric for statistical processing is species richness and number of total birds per sampling point. In order to link birds to structural variables at the stand scale, it is extremely useful to classify species into ecological guilds, for example: climbers that obtain food from the bark of tree trunks and branches, tree cavity nesters, birds that nest and feed in tree canopies, birds of the shrub layer of the understory, and birds that breed and feed on the ground. They can also be classified according to ground cover type at the landscape scale: forest specialists, generalists (birds commonly found in both forests and open spaces) and open space birds (birds exclusive to scrublands, pastures and/or crops).

Figure 20. *Blackcap (*Sylvia cantillans*), a bird found in the understory and shrubby habitats and blue-breasted nuthatch (*Sitta europaea*), a species that feeds on trunks and thick branches and breeds in tree cavities (photos: Eudald Solà).*

8.3. BATS

Most of the more than 30 species of Iberian bats use forests at some point in their life cycle, whether for hunting, mating, breeding, hibernating or as temporary roosts. However, some species are closely linked to forest environments: the arboreal bats (Guixé and Camprodon 2018).

A forest's capacity to host bats is closely dependent on the tree structure. Very dense forests make movement, hunting flights and the search for roosting places difficult. Vertically heterogeneous vegetation and floral richness are also key for ensuring a diverse range of arthropod prey. A final determining variable is the availability of the types of tree cavities specific to each species. Not just any cavity will do: each species of arboreal bats has its own preferences. Noctule bats favour woodpecker nests, long-eared bats nest in small hollows and barbastelle bats roost in crevices under bark. When the availability of good cavities is limited, the hosting capacity of the forest will be lower and there is a higher probability of predation (Guixé and Camprodon 2018). A colony of arboreal bats uses several cavities in the same stand throughout the year (Tillon et al. 2016). Bats hunt in open spaces and drink at water holes. Therefore, their value as indicators lies more at the estate or landscape scale than at the stand scale, which is used mainly for roosting.

Bat censuses are carried out using automatic ultrasound recording equipment, following the ChiroHabitats bat monitoring protocols. The monitoring is performed remotely and for multiple species. Ultrasound analysis now allows recordings to be analysed at species level, although some are not easily distinguishable and are grouped into "phonic groups". Bioacoustics is a constantly evolving technology. There are different models of recorders, varying in performance and price, as does the software for automatically identifying large data packets.

To get a representative sample of the richness and activity of bats in the stand it is important to record over several nights. The ChiroHabitats protocol specifies recording at between 4 and 7 sites consecutively. For maximum efficiency, the recorders can be left on for seven days, programmed to record each night. This allows the recordings to be collected on the same day each week, facilitating logistics if sampling takes place over several weeks.

To process the recordings, those with a similar average number of detected calls are selected, discarding extreme values (e.g. nights with few contacts due to rain or wind). Different recording periods can be selected, for example, one period per season of the year, for long-term population trend monitoring. However, to correlate bat diversity to habitat variables at the stand scale it is best to sample during the breeding season, from late June to mid-July, preferably (from 15 May to 15 August at the earliest and latest). The recording is programmed from half an hour before sunset until half an hour after sunrise.

Forest bats roost in tree cavities and their active range includes the forest and open spaces, from a few hundred metres to several kilometres away, depending on the species. Just one recorder is located in each stand, therefore, in the location with the easiest access and best structure, ideally in the centre of the stand.

The data is processed by taking the average IBP and/or RedBosques figures for the dasymetric sites in the stand. The most commonly used metric for statistical processing is the average species richness and the average number of observations per species or phonic group. In order to better correlate bat numbers to structural variables at the stand scale, it is extremely useful to classify species into ecological guilds. The most useful classification distinguishes between strict arboreal species that usually roost in tree cavities, forest-feeding species that usually hunt in the forest, and generalist species that may frequent the forest, but usually hunt in open spaces and roost in cracks and cavities in rocks or buildings.

As mentioned above, some species are not easily identifiable. These include arboreal species, such as most species of the genus *Myotis, Plecotus* and *Nyctalus*. If information is needed on these species, echolocation recording can be combined with nocturnal trapping sessions (using mist nets and harp traps). Trapping also allows radiofrequency transmitters to be fitted onto captured individuals in order to locate their colonies and identify the trees and stands where they roost. With two groups working together (e.g. one team inside the stand and another in streams or ponds) most species can be trapped in one night.

Another complementary monitoring method is the use of special bat boxes. They can be placed in groups of 3 to 5 boxes per stand of about 8-10 ha, separated by a few tens of metres. Different models can be used to encourage different species, and they must be placed in flying zones away from direct sunlight. They also serve to improve the habitat for rare or endangered arboreal bat species by providing artificial roosts where natural tree cavities are scarce. Bats take months to occupy roosting boxes after they have been installed, needing time to locate them and get used to using them. So roosting boxes should be surveyed one year after installation. There are countless models of boxes, some designed for specific species. They can be made of wood or "wood cement". They are installed hanging from a branch or tied or nailed to the trunk in forest clearings or next to a forest track, at 3-5 metres above ground. They are checked in daytime and it is advisable to do it in June-July (breeding season) and in September-October (mating season). We recommend box models with an opening at the base, which can be checked using a torch from the foot of the tree, without having to climb the tree and open it. In autumn, occupancy tends to be higher, as bats concentrate in cavities and boxes to mate. Bats must be only be handled by a specialist with valid trapping permits.

Figure 21. *Small noctule bat (*Nyctalus leisleri*) (photo: Xavier Florensa).*

Figure 22. *Bat roosting box (photo: Jordi Bas).*

8.4. MOSSES

Mosses and liverworts (bryophytes) grow in very humid conditions, so they are usually associated with dense canopies. They thrive in shady areas and, on a small scale, on trunks and large rocks that receive little sun. In extremely humid conditions, where there is frequent fog, they can form extensive green blankets. In more common conditions they prefer to grow on durable substrates, such as rock outcrops and stumps, with the humidity and temperature conditions typically found in forest interiors. Mosses help conserve the ambient humidity of wood and soil, which is beneficial for other species such as fungi, vascular plants and invertebrates. They also provide habitats for small invertebrates such as nematodes and molluscs. Although they can be found in any forest that meets their needs in terms of humidity, temperature and sunlight, the dense canopies and long-term stable conditions of mature forests facilitate species richness and abundance. Some species have also been identified as characteristic of advanced stages of wood decay (Crites and Dale 1998).

Bryophyte sampling is based on estimating the taxonomic richness of the stand and reliably measuring the coverage of a representative sample of species on a sample of substrates, paying special attention to epiphytic mosses on live tree trunk bark. Fieldwork can be carried out at various times of year, as species can be identified from the external appearance of the gametophyte. Sampling sites must be located at the centre of the dasymetric zones to obtain the combined indicators detailed in this guide. If the central area is not suitable for sampling (e.g., if the conditions are excessively heterogeneous and could result in unrepresentative data), a suitable site must be found nearby. It must be within the stand and as far as possible from the stand edge.

The recommended sampling area is 10 metres in radius. For each plot, all the bryophyte species found on every substrate (live and deadwood, rocks, slopes and soil) are recorded, with an estimate of cover (with a value interval of 5% except for the lowest level of cover, which is 1%). In the case of bryophytes growing on rocks, the coverage is estimated visually, as it is not possible to permanently mark the sampled area on rock.

To sample epiphytic bryophytes, select five trees that are not marked for felling. Select trees with significant coverage of mosses and liverworts (trees without any mosses are excluded) and whose physical characteristics are as stable as possible (good health, verticality of the trunk, etc.). Diseased trees or trees with significant trunk deformities are excluded whenever possible. The normal diameter of each tree is measured and the species is noted, as well as any observations on its health. Only trees of a certain size are selected, for example, with a normal diameter of 20 cm or more. To locate the trees in the future, it is recommended that a numbered plaque be placed at the base of the trunk.

For each tree, four inventories are taken using 10 x 20 cm frames or grids attached to the trunk, two facing north and two facing south, positioned 15 cm from the ground (at the base of the trunk) and 100 cm from the ground, respectively. All the bryophyte species found in the grid are noted and the coverage is estimated. The centre of the top of the grid is marked with two metal nails, so it can be located in the future. The rest of the trunk is also examined for other species that are not included in the inventories, and their presence is noted. The catalogue of epiphytic bryophytes is completed by sampling the other trees in the dasymetric plot, noting the presence of moss species not recorded in the 10 x 20 cm inventories.

Figure 23. *Collecting bryophyte data and detail of a moss-covered holm oak stump in a shady area during sampling in a holm oak forest in La Garrotxa. The area inside the black cardboard frame is a 10 x 20 cm grid, used to estimate coverage for each species. The height on the trunk is measured using a tape measure and samples are collected with a razor (photos: Miquel Jover).*

After each field visit, the samples are dried to avoid degradation, mainly to prevent fungal growth. To identify them, they are rehydrated and taxonomic characteristics are observed with binocular magnifying glasses or a microscope.

Guides that can be used to identify bryophytes include the *Flora dels Briòfits dels Països Catalans* (Casas et al. 2003; Casas et al. 2004) and the *Flora Briofítica Ibérica* (Guerra et al. 2006; Brugués et al. 2007; Guerra et al. 2010; Guerra et al. 2018). It is recommended to conserve the identified samples in a herbarium.

The most commonly used metrics for statistical processing are specific richness and mean cover per sampled tree and/or per stand. In order to correlate mosses and liverworts to structural variables at the stand scale, it is extremely useful to classify species into ecological guilds. This may be by life strategy (pioneer colonisers, short- or long-lived itinerants, perennials, competitive perennials and stress-tolerant perennials), soil acidity (basophiles, neutrophiles or acidophiles), ambient humidity (xerophiles, mesophiles or hygrophiles), temperature (thermophiles, mesothermophiles, cryophiles or indifferent), temperament (shade, half-shade or sun-loving species) or according to how tolerant they are to anthropic factors.

8.5. APHYLOPHOROMYCETIDAE

Mycelial networks of fungi and bacteria perform the essential ecological function of breaking down organic matter (wood, leaves, animal tissues, etc.) and fixing a substantial proportion of the minerals released during decomposition, redistributing these minerals, which are essential for plant growth, over a radius of several metres. Soil mycorrhizae also play an essential role in the functioning of forests. Fungi influence the stand's structure and dynamics, creating habitats for other species. Changes in microclimate conditions due to canopy opening or the edge effect can be detrimental to species that are more sensitive to ambient humidity.

Fungi significantly increase biodiversity, varying from over 200 species on 0.5 ha in a 100-year-old undisturbed mixed broad-leaved forest (Langlois 2000) to over 2,000 in the ancient hardwood forest of Bialowieza (Falinski 1991). Mature forests may host more than twice as many saproxylic fungi as forests managed for timber (Sippola and Renvall 1999).

Polyporaceae are among the most interesting of the Aphylophoromycetidae family for studying the spatial continuity of the variables linked to maturity. They can colonise habitats that are ephemeral, scattered and appear randomly (dead or dying trees). Although some of their spores (they produce several thousand per hour and per cm2) can be transported over long distances (several hundred kilometres), most fall in the immediate vicinity of the fungi (Stenlid and Gustafsson 2001). If the density and turnover rate of large dead trees is too low, the gene flow between populations of saproxylic fungi can be seriously compromised.

Fungi are sampled in 10x10 m plots at the centre of the habitat characterisation sites. A mycological inventory is carried out of fungi of the Aphylophoromycetidae order in each plot. It is also useful to include ephemeral carpophores on soil and other substrates, to obtain a complete picture of fungi diversity. However, as fruiting is very dependent on the time of year and rainfall, these data are difficult to compare from one year to the next. Record all the species of fungi present in each plot, and estimate production by collecting carpophores. For fungi growing on live or dead trunks (corticioid and polypore fungi, etc.), the number of carpophores or the number of clusters is noted and measured to estimate production per tree area (e.g., per basal area). In the case of fungi, when it is not possible to count the number of fruiting bodies, the area occupied is measured and the abundance of fungal classes is estimated by carrying out subsampling within the plot.

After each field visit the samples are identified, weighed and counted and then dried to prevent degradation. If carpophores cannot be sufficiently identified in the field, a sample is taken and analysed in the laboratory (Martínez de Aragón et al. 2007). It is recommended to conserve the identified samples in a mycological herbarium.

To obtain an understanding of the composition and size of the fungal community (saprophytic fungi, parasites, mycorrhizal fungi, etc.), soil and wood samples are collected for mycelium extraction (Castaño et al. 2018). For example, five soil tests are taken per plot and a metagenomic analysis performed to identify the species.

Figure 24. Fomitopsis pinicola *on a stump of pine tree and* Tremella mesenterica *on highly decomposed wood that has also been colonised by mosses (photos: Jordi Camprodon / Juan Martínez de Aragón).*

8.6. VASCULAR FLORA

The vascular flora in forests reflects the diversity of microhabitats (rock outcrops, shady shelters, water points, etc.) and the environmental conditions present (from forest clearings to very dense canopies). Vascular plants characteristic of advanced stages of maturity are few and differ from region to region (Peterken 1996; McComb and Lindenmayer 1999). A species linked to mature forests in one biogeographic region may be found in productive forests or in open habitats in different bioclimatic conditions (Hermy et al. 1999), making it difficult to use vascular plants as indicators of maturity. Meanwhile, the scarcity of forests in the mature and senescent phases means many species associated with these forests are rare or endangered (Wulf 1997).

Mature forests generally host a higher proportion of shade-tolerant species when the canopy is dense and there is a diversity of biological types, including shrubs and lianas (EUROPARC-Spain, 2020a). The continuity over time of the canopy favours species with low dispersal and/or colonisation capacity and relict species, that have become isolated from their original populations or were heavily exploited in the past, such as the yew (*Taxus baccata*). Thinning can increase the total species richness of a stand by favouring the development of heliophyles, including grasses and shrubby nitrophilous species, such as brambles (*Rubus sp.*).

Vascular flora is sampled using flora inventories. In forests, sampling is usually carried out in 10 m radius plots, although the method can be adapted depending on the objectives (e.g. taxonomic groups to be inventoried) and the effort required. The coverage of each species is estimated using percentages, in intervals of 5%, for example, or using the standard intervals used in flora inventories to make sampling easier, in accordance with Braun Blanquet's abundance/dominance scale (+: rare plant or very low coverage, less than 5% 1: abundant plant but with low coverage or rare plant with coverage between 5-10%; 2: very abundant plant but with low coverage or plant with coverage between 10-25%; 3: coverage between 25-50%; 4: coverage between 50-75%; 5: coverage of more than 75%). The sampling period should coincide with the peak growth season for annual, pluriannual and geophyte species. In Mediterranean habitats, May is the peak growth and flowering month for most species. For best performance, two inventories can be carried out, one in early spring (March-April) and one in summer (June-July). The first period is particularly interesting for identifying geophyte species, especially under deciduous trees, as they tend to emerge before the trees fully develop their leaves.

It is recommended to perform a cross transect to estimate the presence of flora species from the catalogue of endangered flora of Catalonia and the red book of endangered species of Catalonia (Sáez et al. 2010). This must also include all protected species (holly and yew), endemic and rare taxa, fruit-producing shrubs, species that are phytosociologically characteristic of the habitats and those that could be of interest for establishing specific technical management approaches. The cross transects are taken along the points of the compass (N, E, S and W) from the centre of the sampling site and must cross the centre of the habitat characterisation plots. The recommended length of each axis is 25 m from the centre of the site with a 4-metre wide band (2 m on each side of the line of progression), which enables the species present to be surveyed. The vertices can be marked with a wooden stake so the survey can be replicated at a later date. The total inventoried area is 100 m per plot. The number of trees and the plant phenology and vitality are recorded and the cover of the shrub and tree strata is estimated.

Figure 25. *Yew (*Taxus baccata*), whose fruits are dispersed by birds, especially the common thrush (*Turdus philomelos*). The image on the right shows a thrush nest in a holly tree (*Ilex aquifolium*) located in a LIFE BIORGEST oak stand (photos: Jordi Camprodon).*

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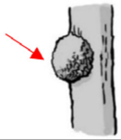
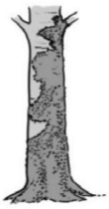
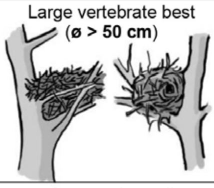
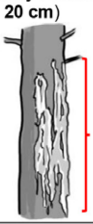
10. ANNEXES

A.1. TREE MICROHABITATS

THE THREE TYPOLOGIES OF THE INDEX OF BIODIVERSITY POTENTIAL (IBP) USED IN V3.0

TYPOLOGY OF TREE-RELATED MICROHABITATS for temperate and Mediterranean regions
(illustrations from Larrieu *et al.*, 2018)

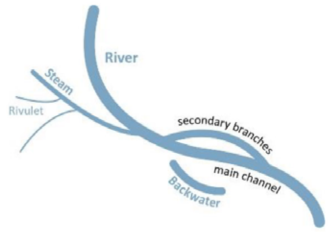
TreM groups	Types present in each of the TreM groups				
1 - Woodpecker breeding cavities	**Small** woodpecker breeding cavity **(ø < 4 cm)**	**Medium-sized** woodpecker breeding cavity **(ø = 4-7 cm)**	**Large woodpecker** breeding cavity **(ø > 10 cm)**	**Woodpecker "flute"** (**≥ 3 breeding cavities** in line, **ø > 3 cm)**	
2 – Rot-holes	**Trunk-base** rot-hole (in contact with the ground) **(ø > 10 cm)**	**Trunk** rot-hole (without contact with the ground) **(ø > 10 cm)**	**Semi-open** trunk rot-hole **(ø > 30 cm)**	**Chimney (ø > 30 cm)** trunk-base rot-hole (in contact with the ground) trunk rot-hole (without contact with the ground)	**Hollow** branch **(ø > 10 cm)**
3 - Insect galleries and bore holes	Insect galleries and bore holes **(ø > 2 cm)**				
4 - Concavities	**Dendrotelm** (water-filled concavity, **ø > 10 cm)**	**Woodpecker foraging excavation** **(ø > 10 cm, depth > 10 cm)**	Bark-lined trunk **concavity** Buttress-root **concavity** **(ø > 10 cm, depth > 10 cm)**		
5 - Exposed sapwood only	**Bark loss** **(S >** 600 cm² = **A4)**	**Fire scar** **(S >** 600 cm² = **A4)**	**Bark shelter** (open at the bottom) **Bark pocket** (open at the top) **(a > 1 cm, « b » and « c » > 10 cm)**		
6 - Exposed sapwood and heartwood	**Stem breakage** **(ø > 20 cm)**	**Limb breakage** (heartwood exposed) **(ø > 20 cm** or S > 300 cm² = A5)	**Crack** **Lightning scar** **(L > 30 cm, l > 1 cm, depth > 10 cm)**		**Fork split** at the insertion **(L > 30 cm)**
7 - Crown deadwood	Dead **branches** **(ø > 20 cm and L > 50 cm,** or **ø > 3 cm and > 20%** of the crown is dead)	Dead **top** **(ø > 20 cm** at the lower part)	Remnants of a **broken limb (ø > 20 cm, L > 50 cm)**		

8 - Twig tangles					
9 - Burrs and cankers	**Burr** 	**Decayed canker** (**ø > 20 cm**) 			
10 - Perennial fungal fruiting bodies	Perennial polypore (**ø > 5 cm**) 				
11 - Ephemeral fungal fruiting bodies	Annual polypore (**ø > 5 cm or number > 10**) 	Pulpy agaric 			
12 - Epiphytic or parasitic crypto- and phanerogams	**Bryophytes** (mosses and liverworts) (**S > 20%** of the trunk area covered) 	Foliose and fruticose **lichens** (**S > 20%** of the trunk area covered) 	**Ivy** and **lianas** (**S > 20%** of the trunk area covered) 	**Ferns** **(> 5 fronds)** 	**Mistletoe** **(10 boules ø > 20 cm)** 
13 - Nests	Large vertebrate best (**ø > 50 cm**) 				
14 - Microsoils	Crown microsoil (at any position in the tree) 				
15 - Fresh exudates	**Sap run** (fresh significant flow, **L > 20 cm**) 	**Heavy resinosis** 			

A.2. COMPARISON OF THE TWO TREE MICROHABITAT CLASSIFICATION SYSTEMS (15 TYPES VS. 10 TYPES)

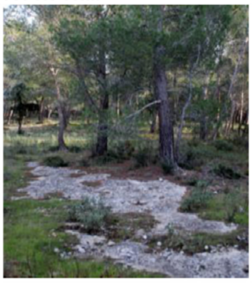
Classification of 15 types (based on Larrieu et al. 2018)	Classification of 10 types (based on Kraus et al. 2016)
1. Woodpecker breeding cavities	CP. Woodpecker breeding cavities
2. Rot-holes 3. Insect galleries and bore holes 4. Concavities	OC: Other cavities
5. Exposed sapwood only	CO: Bark
6. Exposed sapwood and heartwood	DH: Injuries and wounds
7. Crown deadwood	MM: Deadwood
8. Burrs and cankers 9. Twig tangles	FC: Deformation / growth form
10. Perennial fungal fruiting bodies 11. Ephemeral fungal fruiting bodies	HO: Fungal bodies
12. Epiphytic or parasitic crypto- and phanerogams	EP: Epiphytes
13. Nests	NI: Nests
14. Microsoils 15. Fresh exudates	OT: Others

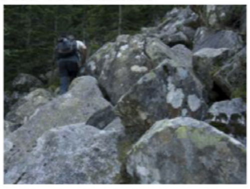
A.3. AQUATIC HABITATS

TYPOLOGY OF AQUATIC HABITATS		
Types of aquatic habitats	**How to identify them?**	**Comments**
Spring or seepage  © L.L.	A point where water emerges from underground. These habitats are limited to the point where the water seeps through. They may be a spring or an area of diffuse seepage on a slope or among rocks. Springs and groundwater seepage can give rise to small streams or marshy areas, which are defined as other habitat types).	At the point where the spring emerges, the water has the same characteristics as its underground water table: usually cool, even in summer, with a high oxygen concentration, although hot springs also exist. In either case, its characteristics differ from those of the streams or marshy areas fed by the spring. The biodiversity of these habitats is quite specific, with some species of high heritage value, such as the Killarney fern (*Trichomanes speciosum*) or the Willow-leaved loosestrife (*Lysimachia ephemerum*).
Small stream, unmaintained humid ditch or small channel  © P.G.	This type includes: > Small natural streams (width < 1 m) in the uppermost reaches of the hydrographic network. > Small man-made streams (width < 1 m), especially drainage or irrigation channels.	 The morphology and characteristics vary and are closely dependent on the rate of water flow, which in turn depends on the slope. They range from mountain torrents and cascades to meanders in lowland reaches. Rivers are mainly permanent, although some can flow intermittently in the Mediterranean region, especially the secondary river branches. Water flow may be either permanent or intermittent in small streams. The presence of specific and often hydrophilic vegetation on riverbanks or riverbeds indicates a habitat which is under water for part of the year. Water can therefore be present whether floods have occurred or not. Riverbanks and riverbeds may be governed by natural dynamics or modified by human activities. However, rivers with consolidated banks and regularly maintained ditches host far fewer species (a rough natural substrate providing shelters and anchorage is especially important when there is a current). Streams can the narrow enough to flow entirely beneath forest vegetation. Any stream or river has alternating stretches of faster or slower-moving water of different heights. As long as the water is visibly flowing, these successive stretches cannot be individualised. However, stretches with stagnant water trapped in hollows are considered as "shallow ponds and water bodies" when the water column is shallow (1 to 3 m on average) and as" lakes and deep water bodies" when the water is deeper.
Stream  © P.G.	No more than 1 to 8 m in width, streams are just downstream from small streams in the hydrographic network. As their catchment basins are small, their flow rate is low.	
River, estuary or delta  © P.G.	Over 8 m in width, these are downstream from streams. They may be subdivided into a main channel and secondary branches connected to it. Rivers may be tributaries of other rivers, while major rivers flow into the ocean or sea, sometimes forming an estuary (in which the tides mix freshwater and seawater) or a delta (when a river divides into several channels near its outlet due to the accumulation of sediment).	
Backwater  © P.G.	A section of a river corresponding to a former channel, which is usually disconnected from the main or secondary riverbed, except very occasionally when the river is in spate (see diagram below).	High seasonal variations in the volume of water and its characteristics (temperature, etc.), which influence the vegetation and fauna present.

TYPOLOGY OF AQUATIC HABITATS		
Types of aquatic habitats	**How to identify them?**	**Comments**
Lake or deep water body  © P.G.	A large, deep inland water body. (Natural or man-made).	At depths of 15 m or more, sunlight no longer penetrates and the water temperature rapidly decreases. Plant species cannot develop below 15 m. The water layers can be mixed by seasonal effects. In the case of artificial lakes (gravel pits, abandoned quarries, reservoirs, dams for irrigation, low water replenishment, hydropower, etc.), the materials used to build up the banks considerably reduce the number of species present. They are still used by wildlife for some purposes (as resting areas for ducks, for example).
Pond, lagoon or shallow water body  © P.G.	Although they are shallow (1 to 3 m in depth on average), the warming action of the sun does not always reach to the bottom of these water bodies. (Natural or man-made).	Depending on the water feeding them and where it flows from, these water bodies can be classified as: > Ponds: freshwater inland water bodies. Fed mainly by their rainwater catchment area. > Lagoons: coastal water bodies separated from the sea by a lido or dune cordon. Lagoon water may be brackish (temporarily or permanently in contact with the sea through a channel) or fresh (completely cut off from the sea and fed by surface run-off, rivers or groundwater). The shallow water promotes the development of both aquatic and amphibious vegetation (the latter being able to survive on dry land). These habitats often support highly productive flora and fauna.
Pool or other small water body  © L.L.	Small stretches of shallow, stagnant water (maximum 5000 m^2, up to 2 m in depth). The whole water column receives sunlight and plants can take root anywhere on the bottom. (Natural or man-made).	This category comprises all small shallow pools of water, including hoof prints, water barrels, drinking troughs and puddles, even if there is no aquatic vegetation due to their ephemeral nature or artificial construction. They are fed by rainwater, surface run-off or seepage. Pools can therefore be affected by climatic variations and dry up in the summer, especially in the Mediterranean zone. Ruts can host certain species but should preferably not be allowed to form as this is not compatible with good soil management.
Peat bog  © P.G.	Wetland habitat where the specific ecology has produced peat soil (organic matter that cannot break down well because of the asphyxiating conditions caused by the permanent presence of stagnant or very slow-moving water).	Peat bogs are highly diverse. Some are acid, others alkaline (also referred to as "low marshes"), and characterised by very different plant associations. Acid peat bogs are dominated by *Sphagnum* (indicators of cold climatic episodes in the past) and carnivorous plants, and alkaline bogs by *Carex*. Large peat bogs may be associated with streams or rivers and may contain stretches of water. They are also feeding, resting and reproduction zones for animal species seeking an undisturbed environment.
Marshy area  © P.G.	A wetland area where the soil is permanently saturated and often covered with a layer of stagnant water that does not form peat. The water level varies but there is always enough to support hydrophilic vegetation.	Marshes vary widely in size, occupying hollows and gently sloping land, especially in marshland regions. Marshes are often associated with springs, streams and water bodies of various types.
Sea or ocean  © P.G.	Salt water body.	The forest is rarely in direct contact with water, but some forests can be very close to water, especially on steep coastal slopes and rocky shores.

A.4. ROCKY HABITATS

TYPOLOGY OF ROCKY HABITATS		
Types of rocky habitats	**How to identify them?**	**Comments**
Cliff or rock wall higher than that of adult trees  © P.G.	Sub-vertical rock wall several dozen metres in height, always higher than that of adult trees.	Composite habitat due to its large size. Large temperature differences on unshaded sections, very dry conditions due to wind pressure and lack of standing water.
Rock wall smaller than that of adult trees  © L.L.	Rocky wall or ledge of low height (smaller than that of adult trees).	Composite habitat rich in varied micro-reliefs, characterized by shady and cool conditions due to the presence of trees (at least in the adult stage).
Rock slab  © P.G.	An extensive sub-horizontal rocky outcrop	The horizontal surface facilitates: > Development of lithosols favourable to plant life; > Formation of small temporary pools of water.
Lapiaz or large fresh fracture  © P.G.	A carbonate rock surface with regular fissures of varying depths carved out by dissolution of the rock. This type also includes single large, deep fractures across a slab up to several metres in length.	A composite habitat made up of a rock slab or block with fissures where specific climatic and light conditions create a cool, moist and shadowy environment.
Cave or chasm  © P.G.	Only the opening is visible.	Very specific microclimatic and light conditions: > Constant temperature and humidity; > Light decreases away from the opening, sometimes to the point of complete darkness.
Unstable scree  © P.G.	An unstable accumulation of stones and rocks.	Little or no decomposing organic matter. Instability maintained by: > Shifting, e.g. by a passing large mammal; > Impacts of falling rock (e.g. from an unstable cliff).

TYPOLOGY OF ROCKY HABITATS		
Types of rocky habitats	**How to identify them?**	**Comments**
Stable rock pile  © L.L.  © P.G.	An accumulation of stabilised stones and rock, either natural (stable scree) or artificial (piled-up stones, stone wall or ruin).	Between the rocks and boulders, presence of decomposing organic matter or fine soil in smaller proportions than the rock and sometimes in only small quantities. In scree, all the communicating micro-cavities make up a particular habitat referred to as a "shallow subterranean habitat", which hosts highly specialised arthropods.
Pile of boulders  © N.G.	A pile of very large boulders (> 2 m).	Large empty spaces between boulders. Frequently produce cold humid conditions between boulders.
Large rocks or rock outcrops other than slab or lapiaz  © P.G.	These are medium-sized rock elements: > Large blocks (from 20 cm to 2 m in height, covering a significant surface area); > Rock outcrop of the underlying rock, that does not form a slab or lapiaz.	Medium rocks, moderately composite, but when many are present in a woodland, they offer habitats in different situations that are particularly attractive to invertebrates and reptiles
Outcropping pebble bank  © P.G.	An accumulation of pebbles in the floodplain of a river (all stony habitats present in the riverbed itself are included in the aquatic habitat category).	Pebbles that may shift when a river is in flood. The pebbles are often partly covered with vegetation, but only sparsely vegetated deposits are included in this type.
Deposit of fine sediments, sparsely vegetated  © P.G.	These may be fine sediment deposits: > In the floodplain of a river (the rocky habitats in the stream bed are integrated into the aquatic habitats), deposited during major floods; > In the form of a dune in the littoral zone.	These deposits are gradually vegetated and only sparsely vegetated deposits are included in this type.
Loose vertical bank or wall of loose material, sparsely vegetated  © P.G.	Unlike the rock walls, these walls are made of loose materials, but of sufficient cohesion to be subvertical. They are found: > On the banks of rivers, > Or on heavily eroded sedimentary materials.	Only deposits that are sparsely vegetated are included in this type. These walls are sufficiently loose to allow digging by birds (Bank swallows, Common kingfishers, etc.), insects, etc.

Typology of aquatic and rocky habitats from: Emberger C., Larrieu, L., Rotiel S., Gonin, P.: 2023. *Ten key factors for species diversity in forests. Understanding the Index of Biodiversity Potential (IBP). 2nd edition*. Paris: CNPF-IDF, 2023
Photos: L.L.: Laurent Larrieu; N.G.: Nicolas Gouix; P.G.: Pierre Gonin

A.5. COMBINED FIELD SAMPLING TABLE

STAND DATA SHEET

Complete a stand data sheet for each stand and a plot data sheet for each plot sampled. | The stand data sheet is used to record identification data, samples, stand-scale indicators and factors, supplementary information, and the calculated maturity indicators and IBP factors taken at the plot scale, aggregate stand-scale data, and the assessment score. | A reconnaissance of the stand is necessary prior to data collection, including locating potential sites for carrying out the survey of the plots.

STAND | **Task/project:** task or project for which the sample is taken. | **Restricted data:** Is the data sensitive for publication purposes? | **Name:** stand name. | **Autonomous community:** autonomous community in which the stand is located. | **Province:** province in which the stand is located. **Municipality:** municipality where the stand is located. | **Property:** type of property, public or private. | **Owner:** in the case of public property, indicate the owner. | **Area:** area of the stand, in hectares, determined using map or GIS.

Task/project			☐ **Restricted data**
Name		**Region**	
County		**Municipality**	
Property ☐ Public ☐ Private	**Owner**		**Area** ha

SAMPLING | **Date:** sample date. | **Team:** names of the team members performing the sample (at least, the name of the field team supervisor, or the contractor).

Date _ _/_ _/_ _ _ _	**Team**

HABITAT | **CORINE/LPEHT:** code and name of the most representative forest habitat of the stand based on the dominant species (see list). | **Community interest:** code and name of the forest habitat of community interest (HCI), according to the Habitats Directive, that is most representative of the stand (see list). | **Biogeographic region:** region in which the stand is located according to the Habitats Directive. | **Main tree species:** the two main native tree species that form the canopy of the stand. ⇒ **Sp pp/ac:** code (see list) and/or name of main and companion species respectively. | **CC:** canopy cover (in %). | **Ho:** dominant height, in metres, calculated as the mean of the dominant heights of the species in each plot weighted by its basal area.

CORINE/LPEHT code/name 4 __ . __ __ __

Community interest code/name 9 __ __ __

Biogeographic region: ☐ Alpine ☐ Atlantic ☐ Mediterranean ☐ Macaronesian

Main tree species:	**Sp pp** code/name	**CC** %	**Ho** m	**Sp ac** code/name	**CC** %	**Ho** m

NATIVE TREE SPECIES RB IBP

Species: code and/or name of tree species at any stage of development and population level, with Ht > 0.5 m, with emphasis on those found between plots.

Species code/name:

FOREST LIFE CYCLE PHASES RB

Phase: Indicate the forest life cycle phases present in the stand, provided the occupied area is at least 200 m² (8 m radius), with the exception of the regeneration phase, which can be 100 m² (6 m radius). In the clear and regeneration phases, indicate in the corresponding box whether the space has opened up naturally, due to the fall of trees (dead or otherwise), or due to felling and/or harvesting.

Phase

					
Gap: ☐ Natural ☐ Felling	Regeneration: ☐ Natural ☐ Felling	☐ Occupation	☐ Exclusion	☐ Maturation	☐ Senescence

Aquatic habitats IBP Characteristic natural or artificial aquatic features, permanent or not (see annex).	**Rocky habitats** IBP Characteristic rocky landscape habitats (see appendix).
☐ Springs or seepage ☐ Small stream, unmaintained humid ditch or small channel (width < 1 m) ☐ Stream (width: 1 to 8 m) ☐ River, estuary or delta (width > 8 m) ☐ Backwater ☐ Lake or deep water body ☐ Pond, lagoon ☐ Lagoon or shallow body of water ☐ Pool or other small water body ☐ Peat bog ☐ Marshy area ☐ Sea	☐ Cliff or rock wall higher than that of adult trees ☐ Rock wall smaller than that of adult trees ☐ Rock slab ☐ Lapiaz or large fresh fracture ☐ Cave or chasm ☐ Stable rock pile (stable scree, heap of stones, ruin, stone wall > 20 m) ☐ Outcropping pebble bank (outside stream bed) ☐ Unstable scree ☐ Pile of boulders > 2 m ☐ Large rocks (> 20 cm) or rock outcrops other than slab or lapiaz ☐ Deposit of fine sediments, sparsely vegetated (alluvial deposit outside stream bed, dune) ☐ Loose vertical bank or wall of loose material, sparsely vegetated

FOREST CONTINUITY IBP RB

1956-57 Ortho: proportion of the stand without trees in the 1956-57 orthophotographs | **1945 Ortho:** proportion of the stand without trees in the 1945 orthophotographs | **Forest discontinuity:** the extent to which is there evidence of agricultural activity on the land before 1945. | **Forest continuity:** evidence of continuous forest cover on land observed to be treeless in 1945. | **Reforestation disturbance:** evidence of soil movement activity for the purposes of reforestation throughout the area. | **Historical documents:** review of documents indicating the age of the forest.

1956-57 Ortho, % tree cover: ☐ 91-100% ☐ 76-90% ☐ 51-75% ☐ 26-50% ☐ 11-25% ☐ 0-10%

1945 Ortho: ☐ 100% treeless ☐ partial tree cover ☐ tree cover before 1945

Land details

Forest discontinuity (walls, terracing): ☐ Entire plot ☐ Localised ☐ Not terraced

Forest continuity: ☐ Vestigial trees on the edges of former pastures ☐ Rocky outcrops that still have trees ☐ Other evidence

Disturbance from reforestation: ☐ Ploughing ☐ Tilling between rows ☐ Stump removal

Historical documents:

ADDITIONAL INFORMATION IBP RB

Other species of accompanying flora: selection of key flora that are indicative of the habitat | **Habitats of Community Interest**: other HCI identified in the stand, whether forested or not. | **Other relevant information**: additional information for the assessment, e.g. if deadwood or tree microhabitats are mostly of the same species, if there are islands of senescence, if there are coppices of different composition, etc.) and/or any other stand information that is relevant for the assessment: fauna, orographic position, geology, hydrography, lithology and edaphology, history, etc. | **Documents:** maps, photographs, or documents with information about the stand may be attached to the data sheet.

Other accompanying flora species:
Habitats of Community Interest:
Other relevant information:
Documents:

INDICATORS AND FACTORS | ❶ **For each plot** ⇒ Field data for the corresponding indicator RB, factor IBP or variable (radius and area). | **For the stand** ⇒ ❷ **Figure:** aggregate figure for each indicator, score or variable for the stand. | ❸ **Score**: score based on the classification thresholds in each case.

		❶Plot ▶	1	2	3	4	5	6	7	8	9	10	Stand ▼ ❷Data	❸Score
	Plot radius m													
	Plot area ha													
RB MATURITY INDICATORS	Tree species n species													
	Basal area m²/ha													
	Volume of trees m³/ha													
	Tree strata n strata													
	Diameter classes n dc													
	Exceptional trees (DBH ≥ ED) trees/ha													
	Abundance of standing deadwood m³/ha													
	Abundance of lying deadwood m³/ha													
	Total deadwood abundance m³/ha													
	Proportion of deadwood %													
	Tree microhabitats n types													
	Silvogenetic phases score													
	Forest continuity over time score													
IBP STAND FACTORS	A: Native tree species n genera													
	B: Vertical vegetation structure n strata													
	C: Standing deadwood pieces/ha	LDW												
		MDW												
	D: Lying deadwood pieces/ha	LDW												
		MDW												
	E: Very large living trees (trees/ha)	VLT												
		LT												
	F: Live trees bearing microhabitats trees/ha													
	G: Flower-rich open areas % surface													
CONTEXT FACTORS	H: Forest continuity over time age of the forest													
	I: Aquatic habitats number of types													
	J: Rocky habitats number of types													

SAMPLING AREA AND NUMBER AND SIZE OF PLOTS

The sampled area must represent between 15% and 50% of the stand area and be at least one hectare ①. It is highly recommended to carry out the sampling on circular plots. This is the guidance contained in the protocol. Survey as many plots of any radius as necessary for the entire sampled area to meet the requirements ②. Sampling larger plots is only appropriate in very small stands that are not steeply sloping and/or with an abundant understory. The minimum radius is 17.8 m in all cases.

① Sample area as a proportion of stand area	Stand (ha)	< 7	7-12	13-18	19-24	25-30	31-36	37-42	43-48
	Minimum sample (ha)	1	2	3	4	5	6	7	8
	Maximum sample (ha)	3	6	9	12	15	18	21	24

② Number of plots needed to sample 1 ha based on radius and area	Number (n)	1	2	3	4	5	6	7	8	9	10
	Radius (m)	56.4	39.9	32.6	28.2	25.2	23.0	21.3	19.9	18.8	17.8
	Area (ha)	1.00	0.50	0.33	0.25	0.20	0.17	0.14	0.13	0.11	0.10

STANDING DEADWOOD RB IBP

Plot radius ⇒ From 17.8 to 56.4 m: sample of standing dead trees of any species, in any state of decay of Ht ≥ 1 m and DBH ≥ 17.5 cm, whole trees and snags.
For each species ⇒ Species: code and/or tree species name. | **Ht**: height in metres. | **DBH**: diameter at breast height, in cm. If Ht < 1.30 m, it is not necessary.

Species code/name	**Ht** m	**DBH** cm	**Ht** m	**DBH** cm	**Ht** m	**DBH** cm	**Ht** m	**DBH** cm	**Ht** m	**DBH** cm	**Ht** m	**DBH** cm	**Ht** m	**DBH** cm	**Ht** m	**DBH** cm

LYING DEADWOOD RB IBP

Plot radius ⇒ **From 17.8 to 56.4 m**: sample of pieces, whole or part thereof, of deadwood of any species, in any state of decay with Lg ≥ 1 m and diameter (Dm) ≥ 17.5 cm.
For each species ⇒ Species: code and/or species name. | **Lg**: length of the piece, or part thereof, with Dm ≥ 17.5 cm. | **Dm**: diameter of the piece at the midpoint of its length, in cm.

Species code/name	**Lg** m	**Dm** cm	**Lg** m	**Dm** cm	**Lg** m	**Dm** cm	**Lg** m	**Dm** cm	**Lg** m	**Dm** cm	**Lg** m	**Dm** cm	**Lg** m	**Dm** cm	**Lg** m	**Dm** cm

TREE STRATA RB

Plot radius ⇒ **15 m**: area covered by living trees, visualised in terms of four strata of equal height up to the dominant height The emergent stratum (5) refers to generally isolated trees whose height is greater than that of the general canopy.
CC ≥ 20%: indicate if the stratum's CC is greater than 20%.

					
CC ≥ 20%:	☐ **1** (0 < Ht ≤ ¼)	☐ **2** (¼ < Ht ≤ ½)	☐ **3** (½ < Ht ≤ ¾)	☐ **4** (¾ < Ht ≤ H_0)	☐ **5** ($H_{dom.}$ > H_0)

VERTICAL VEGETATION STRUCTURE IBP

Plot radius ⇒ **From 17.8 to 56.4 m**: coverage of woody and herbaceous vegetation strata by height.
CC ≥ 20%: indicate if the stratum's CC is greater than 20%.

CC ≥ 20%:	☐ Herbaceous and semi-woody vegetation	☐ Very low woody vegetation (Ht < 1.5 m)	☐ Low woody vegetation (Ht: 1.5-5 m)	☐ Mid-height woody vegetation (Ht: 5-15 m)	☐ Tall woody vegetation (Ht > 15 m)

FLOWER-RICH OPEN AREAS IBP

Plot radius ⇒ **From 17.8 to 56.4 m:** surface area of open spaces with permanent or temporary flowering vegetation.
Surface area: surface area in m² for each type of open space. | **% flowering species:** proportion of the area of open spaces occupied by flowering species. | **Length:** length of forest edge spaces in metres.

Openings or clearings: surface m² x **% flowering species =** m²	**Total:** openings or clearings + low-density areas + open spaces = m²
Low dense areas: surface m² x **% flowering species =** m²	
Forest edges: length m x 2 m width = m² x **% flowering species =** m²	

PLOT DATA SHEET

Complete a plot data sheet for each plot sampled. It is used to record field data sampled at plot scale using either Red Bosques (RB) or IBP standards. | Plots should be located on sites containing features that denote mature forests and/or are important for biodiversity (deadwood, large and/or exceptional trees, etc.). | Plot sizes and distances are measured on the horizontal plane, not following the slope of the land. | It should be noted that the size of the plot depends on the area that needs to be sampled (see tables in the stand data sheet). This size corresponds to all elements, except for live trees of DC 20 and 25 and the tree strata.

PLOT

Number: correlative numerical identifier for the plot (e.g., 1/5, 2/5, 3/5...). | **Code**: plot code, if different from the number. | **Stand**: name and/or code of the stand to which the plot belongs. **Coordinates:** geographic coordinates (always in ETRS89/EPSG:25831) of the central point of the plot, in metres and indicating the zone, if different from 31. | **Site quality:** see document Piqué, M. et al., *2014. Tipologies forestals arbrades. ORGEST*. CPF. Gencat.

Number:	**Code:**	**Stand:**

Coordinates ETRS89:	Zone __ __	UTM x m __ __ __ __ __ __	UTM y m __ __ __ __ __ __ __	**Site quality:** ☐ A ☐ B ☐ C

SAMPLE

Date: sample date. | **Team:** names of the team members performing the sample (at least, the name of the field team supervisor, or the contractor). | **Plot radius:** plot size, in metres, depending on the number of plots in the stand and the minimum sampling area required. ***

Date: _ _ /_ _ /_ _ _ _	**Team:**

Radius of the plot m:	☐ 56.4	☐ 39.9	☐ 32.6	☐ 28.2	☐ 25.2	☐ 23.0	☐ 21.3	☐ 19.9	☐ 18.8	☐ 17.8

LIVE TREES RB IBP

Plot radius ⇒ **10 m:** count of all trees, native or not, in DC 20 (DBH ≥ 17.5 cm) and DC 25. **From 17.8 to 56.4 m:** count of all trees, native or not, in DC 30 to DC 55, and measurement of the DBH of all trees with DBH ≥ 57.5 cm. | **Other species** of DBH < 17.5 cm and Ht ≥ 50 cm. | CC of native tree species (Ht ≥ 50 cm).

For each species ⇒ Species: code and/or tree species name (see list). | **Ho**: dominant height, average of the three largest standing trees in DBH of the plot. | **ED**: exceptional diameter, ED (cm) = 3 x Ho (m) (see equivalence table ⇩). | **DC 20→DC 55:** number of trees in each diameter class present (take into account the plot radius in line with DC). | **DBH ≥ 57.5**: DBH of each tree exceeding 57.5 cm in the variable radius plot. || **Other species:** code and/or name of other species present in DC other than those detailed above. || **CC:** canopy cover fraction for all native tree species.

Ho m	≤ 10	11 ¦ 12	13 ¦ 14	15	16 ¦ 17	18 ¦ 19	20	21 ¦ 22	23 ¦ 24	25	26 ¦ 27	28 ¦ 29	30	31 ¦ 32	33 ¦ 34	35	36 ¦ 37	38 ¦ 39	≥40
ED cm	27.5	32.5	37.5	42.5	47.5	52.5	57.5	62.5	67.5	72.5	77.5	82.5	87.5	92.5	97.5	102.5	107.5	112.5	117.5
DC	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**100**	**105**	**110**	**115**	**120**

RB ⇒ **Exceptional trees** DBH cm > 3 x Ho m →

IBP ⇒ **LT** DBH 37.5 – 57.5 cm | **VLT** DBH ≥ 57.5 cm →

VLT DBH ≥ 37.5 cm / Site quality / Species: *Crataegus, Rhamnus, Phyllerea Arbutus, Acer, Pyrus, Prunus*, etc. →

Plot radius ⇒			*10 m*		*From 17.8 - 56.4 m*													
Species code/name	Ho m	**ED** cm	**DC 20**	**DC 25**	**DC 30**	**DC 35**	**DC 40**	**DC 45**	**DC 50**	**DC 55**	**DBH ≥ 57.5** cm							

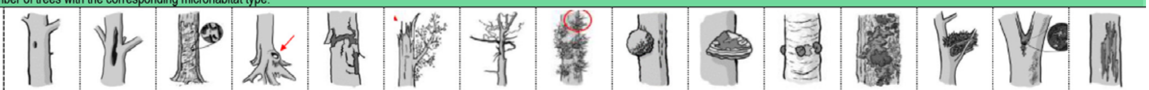
Other species:	**Native CC** ☐ < 50% ☐ ≥ 50%

TREE MICROHABITATS RB IBP

Plot radius ⇒ **From 17.8 to 56.4 m:** sampling of live trees of DBH ≥ 17.5 cm with each of the 15 tree microhabitat types (see table ⇩). If there are several types of microhabitat in the same tree, they are counted as different trees. If a tree has more than one microhabitat of the same type it is counted as one.

Microhabitat types: 1. Woodpecker breeding cavities | **2. Rot-holes** (Ø > 10 cm or > 30 cm in semi-open or open cavities) | **3. Insect galleries and bore holes** (Ø > 2 cm) | **4. Concavities** (Ø > 10 cm, D > 10 cm) | **5. Exposed sapwood** (S > 600 cm² or split bark > 1 cm, W and height > 10 cm) | **6. Exposed heartwood and sapwood** (stem breakage Ø > 20 cm, broken branch at trunk level (S > 600 cm² = A4, or Ø > 20 cm); split of W > 1 cm, D > 10 cm and L > 30 cm) | **7. Crown deadwood** Ø > 20 cm and L > 50 cm or Ø > 3 cm with > 20% of crown dead) | **8. Burrs and cankers** (Ø > 20 cm) | **9. Twig tangles** (witches' broom > 50 cm; offshoots > 5) | **10. Perennial fungal fruiting bodies** (Ø > 5 cm) | **11. Ephemeral fungal fruiting bodies** (Ø > 5 cm or N > 10) | **12. Epiphytic or parasitic crypto. And phanerogams** (mosses, lichens or lianas > 20% of the trunk; mistletoe >10 balls > 20 cm, ferns > 5 leaves) | **13. Nests** (> 50 cm) | **14. Microsoils** (crown, at any height) | **15. Sap and resin exudates** (length> 20 cm) | *Ø: diameter; S: surface; L: length; W: width; N: number: D: depth.*

Trees: number of trees with the corresponding microhabitat type.



microhabitat type	1. **Cavities made by woodpeckers**	2. Cav. organic matter	3. Insect galleries and bore holes	4. Concavities	5. Exposed sapwood	6. Exposed heartwood and sapwood	7. Deadwood in crown	8. Burrs and cankers	9. Twig tangles	10. Perennial fungi	11. Ephemeral fungi	12. Epiphytes or parasites	13. Nests	14. Microsoils	15. Sap and resin exudates
Trees n															

A.6. LIST OF CORINE/LPEHT HABITATS

Adapted habitat list from the Spanish Standard List of Terrestrial Habitats. The primarily Mediterranean (MED) formations are indicated (x). These include variants mixed with other species and reforested habitats.

CODE	NAME	MED
41	**Deciduous broad-leaf forests**	
41.1	Beech (dominated by *Fagus sylvatica*)	
41.3	Ash (*Fraxinus* excelsior)	
41.5&1	Acidophilic oak (*Quercus petraea*)	
41.5&2	Acidophilic oak (*Quercus robur*)	
41.6	Pyrenean oak (*Quercus pyrenaica*)	X
41.7&1	Downy oak (*Quercus humilis or hybrids*)	X
41.7&2	Portuguese oak (*Quercus faginea* s.l.)	X
41.7&3	Algerian oak (*Quercus canariensis*)	X
41.83	Maple (*Acer* spp.)	X
41.84	(Meso-)supramediterranean forests with abundant linden trees (*Tilia platyphyllos*)	
41.85	European nettle tree (*Celtis australis*)	
41.86	Non-riparian forests of *Fraxinus angustifolia* or *F. ornus*, sometimes with oak or holm oak	X
41.9	Chestnut (forests dominated by *Castanea sativa*)	X
41.A	European hornbeam (*Carpinus betulus*)	
41.B	Birch (excluding riparian or marshland)	
41.D	Aspen-dominated forests (*Populus tremula*)	
41.E	Rowan (*Sorbus aucuparia*)	
42	**Coniferous forests**	
42.&1	Silver fir (*Abies alba*)	
42.19	Spanish fir (*Abies pinsapo*)	
42.4	Mountain pine (*Pinus uncinata*)	
42.5	Scots pine (*Pinus sylvestris*)	
42.6	Austrian pine (*Pinus nigra* s.l.)	X
42.8&1	Maritime pine (*Pinus pinaster*)	X
42.83	Stone pine (*Pinus pinea*), natural or semi-natural groves	X
42.84	Aleppo pine (*Pinus halepensis*)	X
42.9	Canary Island pine (*Pinus canariensis*)	
42.A2	Spanish juniper (*Juniperus thurifera*)	
42.A6	Tetraclinis (*Tetraclinis articulata*)	
42.A7	Common yew (*Taxus baccata*)	
42.A81	Canary Islands juniper (*Juniperus cedrus*)	

42.A9	Cade juniper (*Juniperus oxycedrus* s.l.)	
42.AA	Phoenicean juniper (exceptional formations of *Juniperus phoenicea*)	
44	**Woods and other forest formations on riversides or wetlands**	
44.1	Alder	X
44.&1	Poplar	X
44.&3	Riverbank willow and bitter willow (*Salix* ssp.)	X
44.35	Black poplar (*Populus nigra*), native to northern Iberian Peninsula	
44.62	Mediterranean riverbank field elm (*Ulmus minor*)	X
44.63	Mediterranean riverbank narrow-leaved ash (*Fraxinus angustifolia*)	X
44.813	Tamarisk (riverside formations dominated by *Tamarix* spp.)	X
45	**Sclerophyll and laurophyll**	
45.11	Wild olive (*Olea europaea subsp. sylvestris*)	
45.12	Carob (*Ceratonia siliqua*)	X
45.2	Cork oak (*Quercus suber*)	X
45.3	Evergreen oak and holm oak (*Quercus ilex* or *Q. rotundifolia*)	X
45.6	Macaronesian laurel forests	
45.7	Palm groves	
45.8	Holly (forests of *Ilex aquifolium*)	

A.7. LIST OF NATIVE TREE SPECIES

Code and name

100 *Abies alba*
105 *Abies pinsapo*
219 *Abies sp.*
1 *Acer campestre*
2 *Acer monspessulanum*
3 *Acer opalus*
4 *Acer platanoides*
5 *Acer pseudoplatanus*
215 *Acer sp.*
6 *Alnus cordata*
7 *Alnus glutinosa*
216 *Alnus sp.*
224 *Apollonias barbujana*
225 *Arbutus canariensis*
73 *Arbutus unedo*
10 *Betula pendula*
11 *Betula pubescens*
212 *Betula sp.*
88 *Betula tortuosa*
13 *Carpinus betulus*
15 *Castanea sativa*
226 *Celtis australis*
75 *Ceratonia siliqua*
76 *Cercis siliquastrum*
16 *Corylus avellana*
90 *Crataegus monogyna*
217 *Crataegus sp.*
109 *Cupressus lusitanica*
110 *Cupressus sempervirens*
999 *Desconocido*
227 *Dracaena draco*
79 *Erica manipuliflora*
20 *Fagus sylvatica*
228 *Ficus carica*
21 *Fraxinus angustifolia*
22 *Fraxinus excelsior*
23 *Fraxinus ornus*
24 *Ilex aquifolium*
91 *Ilex canariensis*

26	*Juglans regia*
150	*Juniperus cedrus*
111	*Juniperus communis*
112	*Juniperus oxycedrus*
113	*Juniperus phoenicea*
114	*Juniperus sabina*
115	*Juniperus thurifera*
218	*Larix sp.*
92	*Laurus canariensis*
80	*Laurus nobilis*
27	*Malus domestica*
93	*Myrica faya*
232	*Myrica rivas-martinezii*
233	*Ocotea phoetens*
28	*Olea europaea*
199	*Otras coníferas*
99	*Otras planifolias*
234	*Persea indica*
82	*Phillyrea latifolia*
235	*Phoenix canariensis*
83	*Phyllyrea angustifolia*
237	*Picconia excelsa*
122	*Pinus canariensis*
125	*Pinus halepensis*
128	*Pinus mugo (P. montana)*
129	*Pinus nigra*
130	*Pinus pinaster*
131	*Pinus pinea*
134	*Pinus sylvestris*
135	*Pinus uncinata*
85	*Pistacia terebinthus*
239	*Pleiomeris canariensis*
31	*Populus alba*
34	*Populus nigra*
211	*Populus sp.*
35	*Populus tremula*
36	*Prunus avium*
37	*Prunus dulcis*
38	*Prunus padus*
40	*Pyrus communis*
240	*Quercus canariensis*
42	*Quercus coccifera*
43	*Quercus faginea*
45	*Quercus fruticosa (Q. lusitanica)*
49	*Quercus humilis*
46	*Quercus ilex*
47	*Quercus macrolepis*
48	*Quercus petraea*
50	*Quercus pyrenaica*
51	*Quercus robur*
52	*Quercus rotundifolia*
54	*Quercus suber*
87	*Rhamnus alaternus*
57	*Salix alba*
24	*Salix atrocinerea*
58	*Salix caprea*
59	*Salix cinerea*
60	*Salix eleagnos*
61	*Salix fragilis*
62	*Salix sp.*
242	*Sambucus nigra*
243	*Sideroxylon mirmulano*
63	*Sorbus aria*
64	*Sorbus aucuparia*
65	*Sorbus domestica*
66	*Sorbus torminalis*
67	*Tamarix africana*
670	*Tamarix sp.*
137	*Taxus baccata*
245	*Tetraclinis articulata*
68	*Tilia cordata*
69	*Tilia platyphyllos*
210	*Tilia sp.*
70	*Ulmus glabra*
72	*Ulmus minor*
213	*Ulmus sp.*
247	*Visnea mocanera*

A.8. CODE LIST OF HABITATS OF COMMUNITY INTEREST (HCI) AND PRIORITY HABITATS OF COMMUNITY INTEREST (PHCI)

The Habitats Directive defines natural Habitats of Community Interest as natural or semi-natural terrestrial or aquatic areas that, within the territory of the Member States of the EU: a) are in danger of disappearance in their natural range; b) have a small natural range following their regression or by reason of their intrinsically restricted area; c) present outstanding examples of typical characteristics of one or more of the European Union's biogeographical regions. Among them, priority natural habitat types are those that are in danger of disappearance within the territory of the European Union and for the conservation of which the Community has particular responsibility. In the table, these are indicated with an * after the habitat code.

CODE	NAME
9120	Atlantic acidophilous beech forests with Ilex and sometimes also Taxus in the shrublayer (Quercion robori-petraeae or Ilici-Fagenion)
9130	Asperulo-Fagetum beech forests
9140	Medio-European subalpine beech woods with Acer and Rumex arifolius
9150	Medio-European limestone beech forests of the Cephalanthero-Fagion
9160	Sub-Atlantic and medio-European oak or oak-hornbeam forests of the Carpinion betuli
9180*	Tilio-Acerion forests of slopes, screes and ravines
91B0	Thermophilous Fraxinus angustifolia woods
91D0*	Bog woodland
91E0*	Alluvial forests with Alnus glutinosa and Fraxinus excelsior (Alno-Padion, Alnion incanae, Salicion albae)
9230	Galicio-Portuguese oak woods with Quercus robur and Quercus pyrenaica
9240	Quercus faginea and Quercus canariensis Iberian woods
9260	Castanea sativa woods
92A0	Salix alba and Populus alba galleries
92B0	Riparian formations on intermittent Mediterranean water courses with Rhododendron ponticum, Salix and others
92D0	Southern riparian galleries and thickets (Nerio-Tamaricetea and Securinegion tinctoriae)

9320	Olea and Ceratonia forests
9330	Quercus suber forests
9340	Quercus ilex and Quercus rotundifolia forests
9360*	Macaronesian laurel forests (Laurus, Ocotea)
9370*	Palm groves of Phoenix
9380	Forests of Ilex aquifolium
9430	Subalpine and montane Pinus uncinata forests (* if on gypsum or limestone)
9430*	Subalpine and montane Pinus uncinata forests (* if on gypsum or limestone)
9520	Abies pinsapo forests
9530*	(Sub-) Mediterranean pine forests with endemic black pines
9540	Mediterranean pine forests with endemic Mesogean pines
9550	Canary Island endemic pine forests
9560*	Endemic forests with Juniperus spp
9570*	Tetraclinis articulata forests
9580*	Mediterranean Taxus baccata woods

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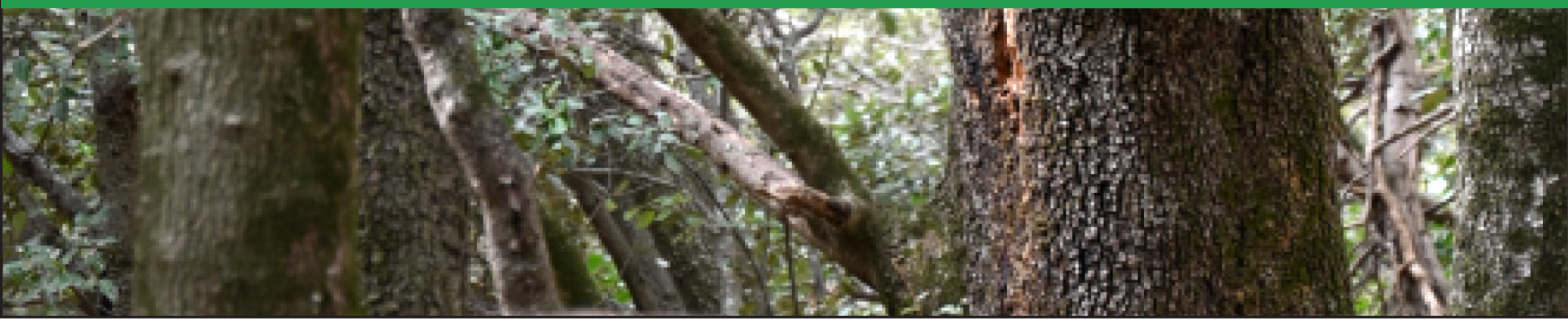

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