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Best management practices for the conservation of black pine (*Pinus nigra*) forests

Making compatible forest production and habitat conservation

Best management practices for the conservation of black pine (*Pinus nigra*) forests

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Index

1.

The habitat of the black pine forests

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1.1. Introduction

The forests dominated by black pine (*Pinus nigra* subsp. *salzmannii*) form a habitat of great interest, being among the most important Mediterranean forest systems. Their importance is related to the species' own characteristics and the associated biodiversity of the habitat, and to the great variety of social uses and functions both in the past and in present times. The human interaction with this habitat has taken place more or less intensely from time immemorial resulting in their current composition and state of conservation.

For these reasons black pine forests require management guidelines that make their uses and functions compatible; from the production of goods (timber, fuelwood, hunting, forest fruits, mushrooms etc.) and ecosystems services to the conservation of the habitat and its associated biodiversity. This guide seeks to offer several guidelines and recommendations to integrate the conservation of the black pine habitat in forest management practices, achieving a multi-functional silviculture considering with differing objectives.

The Life+ PINASSA project has been developed between 2014 and 2018 with the objective of improving the conservation status of the black pine forests within the Natura 2000 network in Catalonia through forest management actions (Figure 1). This guide is one of the main outcomes of the experiences carried out, including demonstrative silvicultural interventions implemented in more than 300 ha and the processes of reflection and debate about the multi-functional silviculture of black pine forests.

Figure 1. Black pine forest within Natura 2000 network, Central Catalan Pre-Pyrenees. Photo: AGS-CTFC.

1.2. Main characteristics of the habitat

Black pine forests (*Pinus nigra* Arn. subsp. *salzmannii* [Dunal] Franco var. *pyrenaica*) make up the priority natural habitat of Community interest described in annex I of Directive 92/43/CEE, on the conservation of natural habitats and of wild fauna and flora. In Catalonia 35% of these forests are within 38 Special Areas of Conservation of the Natura 2000 Network.

***The Guide of Habitats of Catalonia* identifies three areas of occurrence for the black pine forests:** a)the Pre-Pyrenees area; b) southern area (south-eastern Iberian range) ; and c) recent, not yet naturalized afforestations

(Vigo *et al.*, 2005). The mentioned work defines the ecology of this species, occurring at the sub-montane stage, in sub-Mediterranean Medio-European climate, preferably with basic soils and shady orientations. Some of the most relevant species within this habitat include *Quercus faginea*, *Buxus sempervirens* and *Viola willkommii*. In the Pre-pyrenees area other species are *Amelanchier ovalis, Lonicera etrusca, L. xylosteum and Rubia peregrina*, while in the southern area *Genista patens, Acer opalus, Geum sylvaticum and Paeonia officinalis* are typically present.

Annex I Directive 92/43/CEE	9530 * (south -) Mediterranean pine forests of endemic *Pinus nigra*

9530 * (south -) Mediterranean pine forests of endemic *Pinus nigra*	42.632 Pre-Pyrenees black pine forests, the *Ausosegárrico* territory and the northern Mediterranean mountains (until Upper Gaià)
	42.67 Black pine forests or afforestations, without forest understory.
	42.637+ Black pine forests of the southern Mediterranean mountains (from Prades and Montsant ranges to Ports massif)
	43.7713. Mixed forests of *Quercus faginea* and black pine or Scots pine, calcicolous, of low precipitation mountainous area (and lowlands)

This habitat is of great interest considering its associated diversity (both in structural terms and of species composition), since they are transition areas between the subalpine and the xeric Mediterranean conditions. It usually forms relatively large extensions, including landscapes of agro-forestry mosaic and dense forests favouring the presence of nemoral flora and more or less specialist forest fauna. These elements, together with the black pine forests as such, are the main characteristics of the habitat (Blanco *et al.*, 1998; Regato i del Río, 2009).

The black pine can have different roles within the **forest dynamics**, because it can act as a pioneer and frugal species in the forest expansion into open spaces (usually abandoned pastures) and can also be the main species in mature and long-living forests, due to its capacity to regenerate under cover, both its own and that of other species (Beltrán *et al.*, 2012). At the same time, it has an important role in the facilitation of the development of arboreal and shrub species of more or less ombrophilous environments. Thus, the general forest dynamics is usually defined by the species present, which usually have different temperaments and ecological requirements, also generating diverse structures and interacting in relations of competence - tolerance - facilitation. On the other hand, disturbances are also decisive in the dynamics of these forests, being forest fires the most relevant one, because they are closely bound to the forest structure.

In the absence of disturbances leading to a marked change of environmental conditions, the black pine forests develops with a tendency to mono-stratification generating a closed canopy that limits the light reaching the lower layers. However, other species can develop and cohabit in these conditions, like the Mediterranean oaks (*Quercus pubescens*, *Q. faginea*, *Q. ilex*) and maples (*Acer sp*.), among other accompanying species. Conversely, disturbances that suppose an abrupt change of conditions, like high-intensity forest fires have a highly negative impact for black pine in these forests, because it is in a competitive disadvantage for regeneration compared to the Aleppo pine (*Pinus halepensis*, great coloniser of open areas) and the Mediterranean oaks (great sprouters).

The **mixed forests dominated by black pine** are abundant in spite of the limited ecological plasticity of the species. Scots pine (*Pinus sylvestris*) or Aleppo pine use their great plasticity to develop in the habitats of black pine, resulting in conifer mixed forests. Regarding pine-Mediterranean oaks mixtures, these broadleaves have ecological requirements resembling those of the black pine. Anyhow, the black pine does not show a clear dynamics of exclusion toward other species; it mixes more or less intimately in function of the characteristics of the other species. In any case, the dynamics of dominance change are frequent within these forests, especially where the species composition has been influenced by human action in favour or against the black pine.

Lastly, it is necessary to highlight the singularity of the black pine with regard to mature forests (Figure 2). Given the characteristics of the species (high longevity, tolerance to shade, capacity of regeneration under cover, resistance to frost, adaptation to low intensity wildfires in mature stages) and of the habitats it occupies (productive sites with appropriate water regime, soil characteristics and mild temperatures), this species has great potential to generate structures of mature forest, thus constituting an element of first interest within this habitat.

Figure 2. Stand of black pine with characteristics of maturity well above the average of the habitat, located in Ports Natural Park. Photo: AGS-CTFC.

1. 3. Distribution in Catalonia

Pinus nigra is a circum-Mediterranean collective species that occurs in various endemic southern European pine forests. In Catalonia, black pine forests are distributed mainly across the Pre-Pyrenees, the mountains of the pre-coastal ranges and the southern mountains of the south-eastern Iberian range (Figure 3).

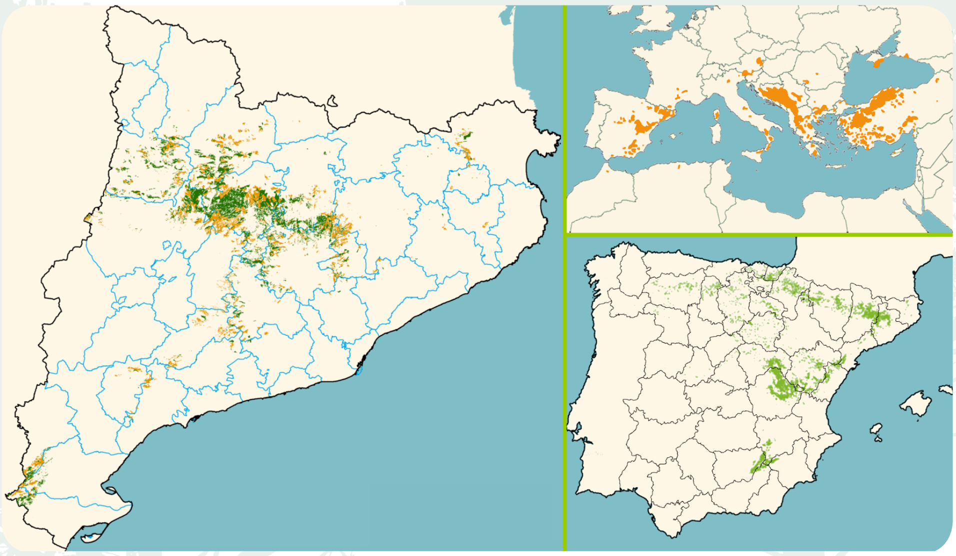


Figure 3. Catalan and Iberian distribution of *Pinus nigra* according to the Forest Map of Spain (DGDRPF, 2016) and world distribution according to Euforgen (Critchfield i Little, 1966). In the map of Catalonia, the areas marked in green indicate pure black pine forests, while the orange ones are mixed forests dominated by this species.

The area occupied by black pine forests has remained stable or has slightly decreased over the last decades, contrary to that observed for other species occurring in the same distribution area like the Scots and Aleppo pines and the Mediterranean oaks. The last Forest Map of Spain (DGDRPF, 2016) calculates in 140,000 ha the extension of these forests in Catalonia, of which some 65,000 ha are mixed stands. Although in general this species shows an area recovery from its historic minimums of the late XIX - early XX centuries, the great forest fires of the 1980s and 1990s led to a significant loss of extension of this habitat.

The location in the Catalan mid-mountain conditions offers a climatology and an orography favouring forest productivity, for which the black pine forests have been object of wood harvesting from time immemorial up to the present, even with the predominant abandonment of rural activities.

1.4. Main threats

The main threat for the habitat of black pine is the current context of global change, where the change in the climatic regime worsens certain problems that can end up being translated into a deterioration of the habitat. **Climate change has an effect on forest fires and on drought and pest incidence, usually increasing the negative impact of these threats.** From an intrinsic point of view, many of these stands are relatively young, not very vital and show simplified structures with little biodiversity, which also increases biotic and abiotic risks.

In parallel, the socioeconomic changes affects the development of these forests and their interaction with the new environmental conditions. The traditional management generated structures with high trees, open canopy and a general lack of understorey, leading to a vertical fuel discontinuity. The Mediterranean oaks and other broadleaved species present were used for fuelwood and their development under the pine cover was limited. Only scattered oaks or holm oaks remain as large trees within former pasture areas, where they were utilized as a feeding complement and for shade. In general, the resulting structure presented little vulnerability to high-intensity fires because of the low amount of fuel and of the distances between fuel layers. These structures, generated by human action, have been present in the landscape for a long time and extended more or less widely in the territory depending on the rural population of each moment.

The socioeconomic changes of the XX century affected forest management, in general reducing its intensity and focusing it on obtaining certain products. Poles for light and telephone infrastructures are an example of a specific black pine product whose extraction can condition the characteristics of the forest. In consequence, the understorey develops both vertically and horizontally, especially the Mediterranean oaks layer previously installed. These species have a good capacity for growth starting from the reserves of the radial system that allows them to develop when they have light and space and they are not used for firewood. Moreover, the extraction of pines for any wooden product is usually carried out with individual technological approaches and with few actions of improvement of the woodland, for which layers of pines are generated with problems of vitality, growth and regeneration. As a result of the whole process, the forest structures have heavier and more continuous fuel loads, larger arboreal density competing for resources and scarce capacity of growth and regeneration of the black pine, for which the habitat is endangered by large forest fires and other factors that condition the persistence of the forest.

Large wildfires, which show a growing intensity over decades, constitute a major threat. The black pine is not adapted to this type of fires (although it is adapted to recurring fires of low intensity), its strategy of regeneration does not allow it to recover its area in the short term, because it depends on the survival of groups of adults to begin a progressive expansion. As a result, the oaks sprouters (that were already in the forest before the fire, even when only as incipient seedlings) and the coniferous colonizers of xeric spaces (Aleppo pine, present or not before the fire) lead the early recovery of the forest. Black pine can only regenerate under this initial cover, so the regeneration of these spaces as habitats of black pine can be compromised if there are not enough adult trees surviving the wildfire.

The large wildfires of the 1990s in central Catalonia generated a great change in forest cover. The black pine forest was substituted by resprouting Mediterranean oaks saplings while nowadays an incipient regeneration of black pine is detectable only near the surviving adults (Figure 4).

Figure 4. Island of adult black pines that survived the wildfire of central Catalonia in 1998, surrounded by the regeneration of oak saplings. A gradual increase of regenerated black pine is observed in these areas (photo taken in 2013). Photo: AGS-CTFC.

Although the **change in the water regime** is uncertain, most models suggest that the annual distribution of precipitation will become more irregular with an expected overall decrease. All this, added to an expected increase in temperature and, in general, of the frequency of extreme climatic events, can lead to drought-induced mortality episodes, especially in dense forests with high shrub cover. Moreover, the changes in climate can also modify the life cycles of pathogenic agents (mainly insects) favouring their development and imbalances with control agents, leading to a weakening and even causing the death of the trees.

Different forest factors like structure, development phase, vitality, understorey or past management can play a decisive role in the capacity of adaptation and the resistance and resilience of the forest to the mentioned threats.

In the case of **relatively young and dense forests** that represent the first phase after the colonization of open spaces, the system has low capacity to support strong competition, hindering the forest from advancing toward states of maturity (Figure 5). At the same time, long-term water restriction can cause high mortality rates and greater vulnerability to pathogens or damage from wind or snow. Furthermore, an excessively simplified structure brings added difficulty to the development of other elements of the ecosystem that contribute to the habitat biodiversity.

Figure 5. Relatively young (40-60 years) and dense forest with excessive competition for resources and with a simplified structure that limits the development of biodiversity. Pictures taken before and after the silvicultural interventions carried out during the Life+ PINASSA project. Photos: CPF.

In the case of **more adult forests**, where long-term silviculture for timber production has been carried out, the structure is usually simplified with a tendency to mono-stratification, particularly when management has been abandoned (Figure 6). Usually, in these forests, the woodland stays in adult phases, where a great variety of stages of development of the trees can be found, but without showing signs of great maturity. The biggest trees (frequently not the most vital) usually remain in the stand, while there is a poor regeneration. On occasions the shade tolerance of the black pine and its capacity to react after a long-time shading leads to **structures with a tendency to irregularity** regarding sizes (Figure 7). In any event, these structures do not usually have relevant viable regeneration that assures the dynamics as an irregular stand, so that in the long term the vitality of the trees diminishes and its continuity can be compromised. In general, this structure shows high vulnerability to crown fires given the continuity of layers. Furthermore, the management of these woodlands has usually actively excluded other arboreal species, although the natural dynamics favours their development under the cover of the black pine. In short, the main threats for these adult forests are their low vitality, the high risk of wildfires and the poor natural regeneration.


Figure 6. Regularized adult (90-120 years) forest where the dominant trees have low vitality and are subject to excessive competition, and the structure does not favour abundant and viable regeneration. Pictures taken before and after the silvicultural interventions carried out during the Life+ PINASSA Project. Photos: AGS-CTFC.


Figure 7. Irregular adult forest, with open canopy favouring the development of shrubs, where the tree layer shows low vitality and the structure does not favour continuous viable regeneration. Pictures taken before and after the silvicultural interventions carried out during the Life+ PINASSA project. Photos: AGS-CTFC.

The forest structure, considering the tree and shrub layers, have a decisive role in the event of a forest fire. When the forest shows a non-well-defined structure, both regular and irregular, that favours the development of the shrub layer leading to vertical fuel continuity, the vulnerability of the forest to generate large wildfires is clearly enhanced (Piqué *et al.*, 2011). Different situations can result in this happening, although management record is usually decisive. When a large wildfire affects black pine forests with these unfavourable structure, the habitat will probably suffer a regression and the black pine will be substituted by other species (Beltrán *et al.*, 2012). In this case, the threat lies in the difficulty to recover the black pine in these areas.

In this sense, **the prevention of large forest fires is fundamental for the preservation of the habitat of the black pine** and it should be approached from various scales, from the landscape to the stand levels (Piqué *et al.*, 2011). In the last years an advance in knowledge concerning high-intensity fires has been made, with respect to typology, regime, behaviour pattern and other factors (Costa *et al.*, 2011). Thus, certain areas can be identified as strategic for the development of a large wildfire, so that actions of prevention and suppression can be more efficient if they are executed there. In general, these strategic areas should host structures with low vulnerability to generate active crown fires (Figure 8). In this case, the threat of large fires is approached with preventive action, focusing on strategic areas that modify the behaviour of the fire toward surface fires that therefore reduce tree mortality and facilitate the tasks of suppression.

Figure 8. Black pine forest located in a strategic area of support for forest fire suppression, where the structure has a decisive role in the behaviour of the fire. Pictures taken before and after the silvicultural interventions carried out during the Life+ PINASSA project. Photos: AGS-CTFC.

2.

Multi-functionality and demands towards the habitat

2. Multi-functionality and demands towards the habitat

2.1. Multi-functionality

Black pine forests simultaneously generate different functions (goods and services), some of them without a specific demand. Forest management is the main tool to guarantee the provision of these multiple functions over time, by means of silviculture applied in agreement with the natural dynamics leading to a forest structure and composition adapted to its characteristics, potentialities and objectives (Beltrán *et al.*, 2012).

The current socioeconomic context, with different demands converging on forests, requires multi-functional forest management to coordinate the prevalent functions and to avoid negative impacts, according to the preferential objectives defined in each case (González *et al.*, 2011). Thus, the long historical interaction of human activity with the forest may have generated situations where certain functions have been affected. Nevertheless, the abandonment of forest management has also contributed in many cases to a loss of multi-functionality, especially of those functions related to the conservation of biodiversity.

2.2. Functions of the black pine forest

The different functions that the forests provide are usually grouped into three types: productive, environmental and social. By means of **productive functions** goods with market value are generated, mainly timber, although there are other products like pastures, mushrooms and hunting (Figure 9 and Figure 10). The goods contributing to well-being and that are assimilated to public goods of indirect use, such as landscape and environment for recreational activities (Figure 11), form **the social functions**. Public goods and services of indirect use, or of no-use, where it is not necessary for a demand to exist, forms **the environmental functions**. The main environmental functions of black pine forests are the regulation of water cycle (Figure 12), the attenuation of erosion, the fixation of atmospheric CO_2, the conservation of biodiversity and value existence, option of donation and legacy.

Hydrological regulation and the attenuation of erosion are especially important environmental functions that the black pine forests perform in mountain areas and in the headwaters, mainly in the Pre-Pyrenees and in the pre-coastal mountains. On the other hand, these forests are an important reservoir of biodiversity, both for the bio-geographic importance of the black pine in Catalonia and for the presence of flora and fauna species with conservation interest.

Figure 9. Productive functions of black pine forests: hunting, mushrooms, timber. Photos: Jordi Bas and AGS-CTFC.

Figure 10. Productive functions of black pine forests: pastures. Photo: Mario Beltrán.

Figure 11. Environmental and social functions of black pine forests: landscape and biodiversity conservation. Photo: Jordi Bas.

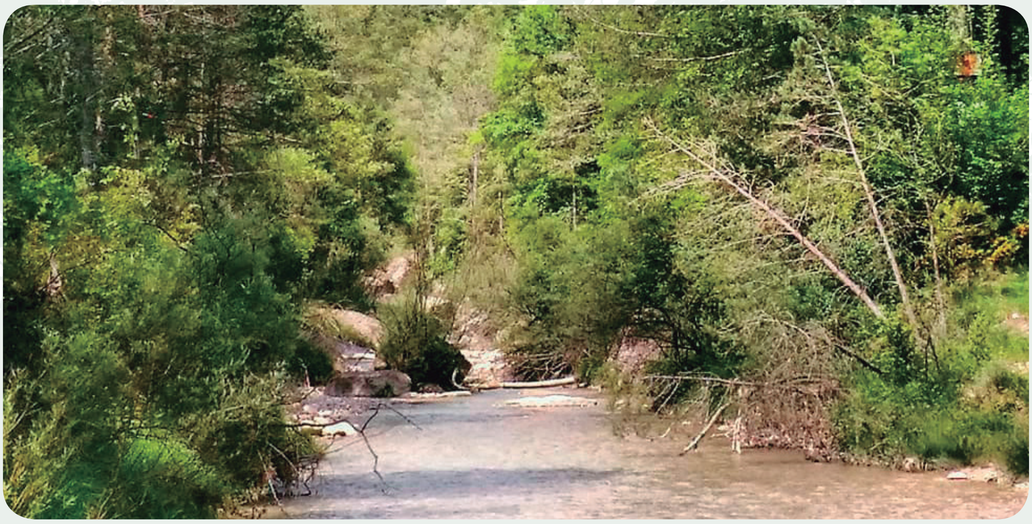


Figure 12. Environmental and social functions of black pine forests: environment for recreational activities and hydrological regulation. Photo: Mario Beltrán.

2. 3. Objectives of multi-functional management

Traditionally, the main demands on black pine forests have been productive, basically timber and fuelwood. Other secondary products include green foliage, pine cones, bark, resin, or torches, in addition to other products obtained from the scrub and the herbaceous layer. The demand for indirect goods of environmental and social functions has been generally subordinated to direct production. However, in the current socioeconomic context, it is necessary to integrate various social demands simultaneously in the management objectives.

> Currently, it is recommended to apply multi-functional forest management with one or more preferential objectives and other additional ones, whenever they are compatible, and also integrating specific measures of conservation to improve habitat biodiversity. In an ideal context, it would be convenient to incorporate the maximum possible functions into the economic balance, in order to avoid a complete link between the market value of the commercialized products and the whole productions of direct and indirect goods and services.

The definition of the management objectives is based on the establishment of priorities among the forest functions, because it is not probable that all the functions are provided simultaneously at maximum level. Prioritization is translated in the assignment of some preferred management objectives. Furthermore, with appropriate sustainable forest management, forests always provide in greater or lesser measure the different functions, besides the preferred objective. The main objectives that can be assigned according to the demands are (Beltrán *et al.*, 2012):

- Timber production. Management is aimed preferably at the obtaining of timber, while the persistence and vitality of the forest is assured and the rest of the functions are guaranteed at an appropriate level, especially the conservation of biodiversity and the landscape quality.
- Production of pasture. Management is focused on maximizing pastoral production under a more or less open cover of black pine, and probably with a significant presence of Mediterranean oaks and other tree species.
- Production of other marketable goods. The management seeks preferably the generation of products other than timber, such as hunting, mushrooms, aromatic and medicinal plants, forest fruits or honey.
- Prevention of large wildfires. Management is focused on the conservation of the forests to reduce the risk of large forest fires. It can be an objective assigned to the whole forest within an area (an increase of resistance to fire) or assigned to certain strategic points (modification of fire behaviour, creation of defence infrastructures).
- Hydrological protection and soil conservation. Management seeks to guarantee forest vitality and functionality to favour the physical stability of the terrain, to avoid erosion and to regulate the hydrological regime of the headwaters and mountain areas.
- Conservation and improvement of biodiversity. Management is aimed at the improvement of the habitat quality for the flora and fauna species present or to be developed. The objective is to create and maintain structural elements, generally maximizing those related to the refuge and sources of food for different species considered of interest.
- Social uses and landscape quality. Management seeks the improvement of the quality of the landscape and recreational environment.

Further objectives, as well as the combination of several of the mentioned ones, can also be established to address the different demands.

The current process of climate and global changes involve a predicted evolution toward generally more restrictive environmental conditions for forest growth and a notable increase of the risk of wildfires (Figure 13). In this context, the choice of objectives has to be particularly precise, so that it is adjusted to the site productive capacity (site index) while always integrating (or reducing) fire risk. Above all, the dynamics of the different species present must be considered to favour the capacity of adaptation of the stands as a premise to guarantee their long-term conservation.

Figure 13. The risk of high intensity fires in black pine forests increase due to the effects of climate change. Photo: Bombers de la Generalitat.

The conservation of black pine forests requires a precise silviculture that bears in mind the current and future site quality, the species ecology and dynamics, and its interaction with other species and other elements of the habitat.

To fulfil the multi-functional demands, including the habitat conservation, in environments with a long record of human interaction and great heterogeneity at the landscape scale, it is appropriate to follow an **integrative management model** (Kraus & Krumm, 2013). This approach is based on one hand on the integration of anthropogenic and natural impacts derived from the forest management for goods production and from the evolution following natural dynamics.

In general, when management is focused on the production of goods, the forests can stay in relatively young phases of natural dynamics. Frequently they lack **the more developed phases of mature forests, where elements that contribute to the value of biodiversity to the habitat can be found**. One of the foundations of integrative management is to incorporate in the younger phases these elements of value typical of the most developed phases, by means of specifically designed actions or adapting generic ones, thus making production compatible with habitat improvement (Figure 14).

The demonstrative actions on the integration of conservation in forest management carried out in the framework of the Life+ PINASSA project have incorporated this strategy of integrative management in their conception (Figure 15).

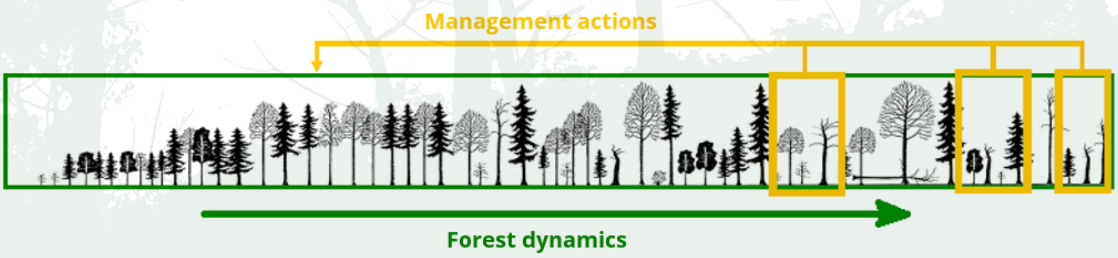
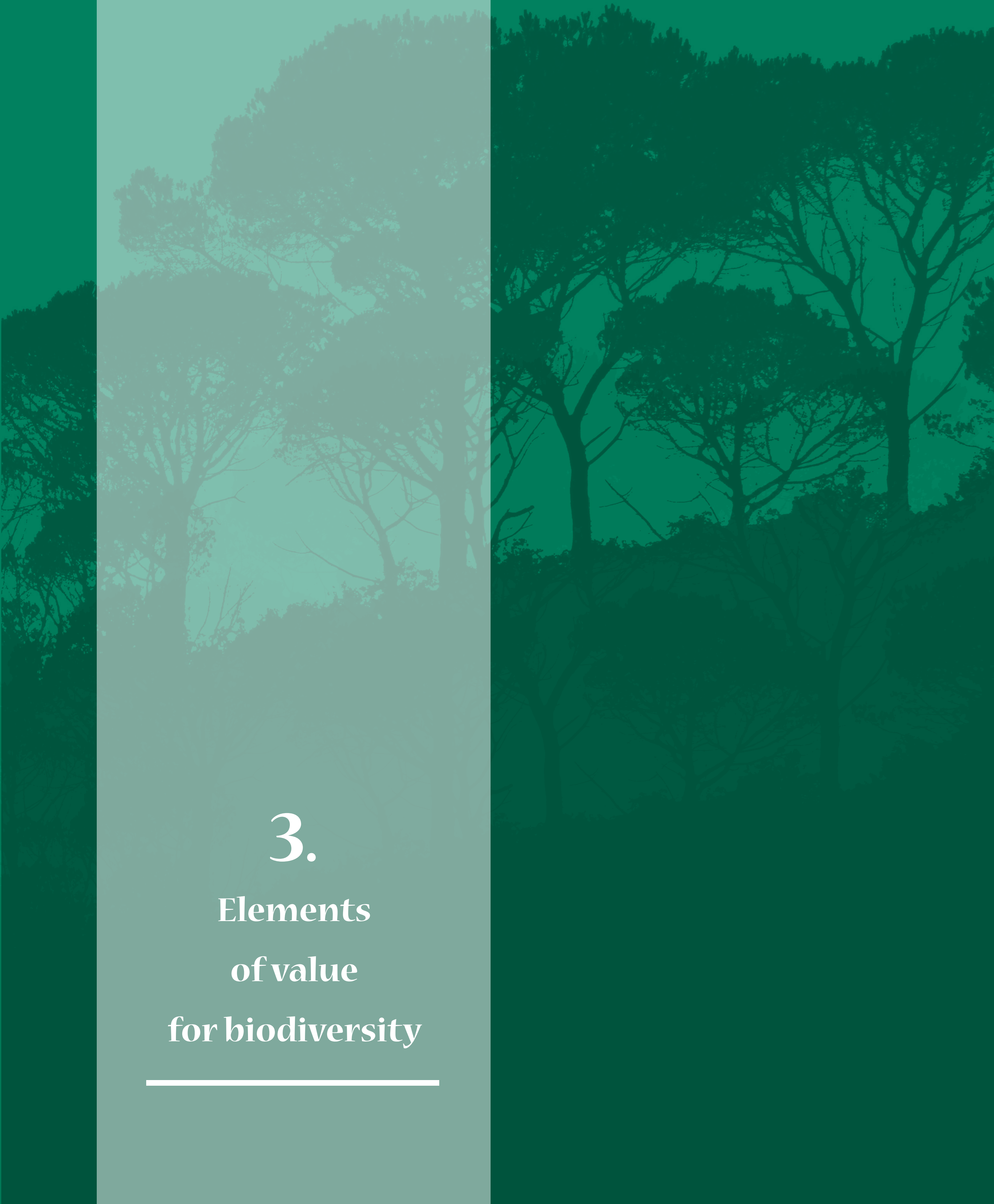


Figure 14. The strategy of integration of valuable elements for biodiversity in the productive phases of the forest (adapted from Kraus & Krumm, 2013).

Figure 15. Black pine forest of the Pre-Pyrenees in an adult state of development, where elements of value for biodiversity characteristic of mature phases begin to appear. Forest management must make productive objectives compatible with the maintenance of these elements, such as large trees, structural heterogeneity of vegetation or dead wood presence. Photo: AGS-CTFC.



3.

Elements of value for biodiversity

3. Elements of value for biodiversity

3.1. General methods for the evaluation of biodiversity

The evaluation of forest biodiversity is a complex discipline that requires expert knowledge and specific methodologies, and in general is seldom considered in the tasks of planning and conventional forest management. Instead of evaluating the presence and state of conservation of all the specimens that form a habitat (vascular flora, mosses, lichens, mushrooms, insects, birds, bats, rodents and other mammals, etc.), **it is more senseful to focus on specific elements (indirect indicators of potential biodiversity) that are more easily assessed:** for example, quantity and type of dead trees, trees with microhabitats suitable to host animals, etc.

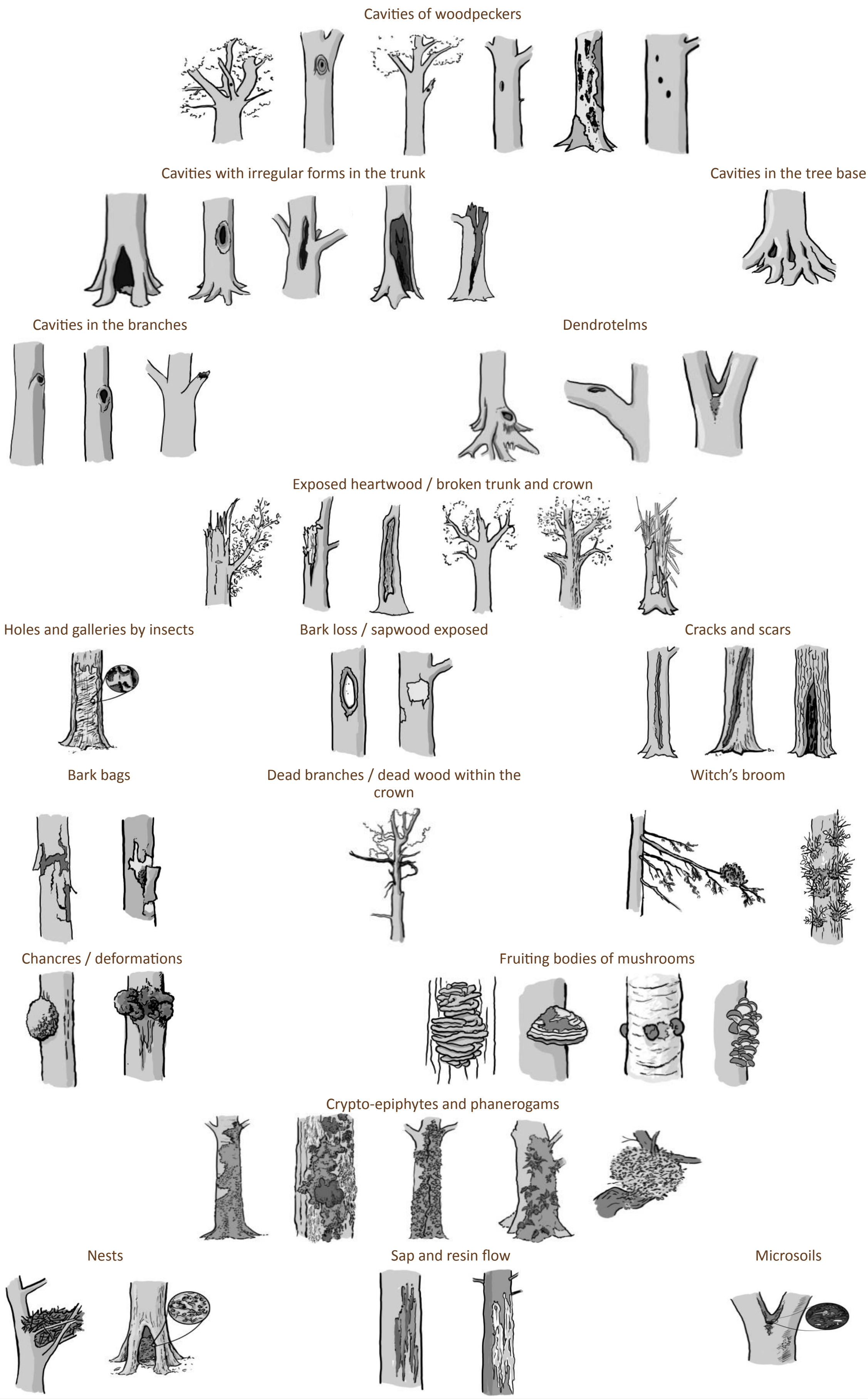
To integrate the improvement (conservation or promotion) of biodiversity in multi-functional forest management it is necessary to **identify the biotic and abiotic elements that contribute the most to the habitat value**. These elements indirectly represent the potential biodiversity that can be hosted, being elements that facilitate shelter, food or reproduction opportunities to the fauna, and the development and reproduction of the flora.

What elements of value for biodiversity should be considered in the management for the conservation of the black pine habitat?

The **list of elements of value for the indirect assessment of the biodiversity** can be very wide and varied. However, efforts have been carried out recently for the harmonization of indicators with a practical approach, focusing on those that are more easily integrated in the forest inventory and planning stages. Some of the most relevant forest biodiversity indicators are:

- Presence of living trees with microhabitats for the fauna (Table 1).
- Presence of large trees and trees singular for their structure or species.
- Presence of standing and lying dead trees, in different states of decomposition.
- Forest gaps, rocky or aquatic environments and, in general, elements that provide heterogeneity to the forest structure both at landscape and stand level.

Table 1. Different microhabitats in living trees, which are elements of value for biodiversity, identified by the Integrate+ project (Kraus *et al.*, 2016).



The case of the Index of Potential forest Biodiversity of Catalonia (IBPC) developed by the Forest Ownership Centre (Government of Catalonia)

The IBPC (Baiges *et al.*, 2018) is a decision support tool for forest management and planning, designed to facilitate the integration of biodiversity conservation criteria in forests managed with other preferential aims. It is applied at stand scale and consists of a list of biodiversity indicators, based on structural stand parameters (vertical layers, presence of large trees, trees with microhabitats, etc.). The IBPC allows assessing the potential of a forest to house biodiversity in a quick and simple way, as well as identifying the specific indicators that could be improved through forest management. The periodic IBPC assessment in a given stand allows to evaluate the evolution of hits state of conservation and the sustainability of its management.

The IBPC has been elaborated from the knowledge of forest structure-biodiversity relations, obtained within the *monitoring programme of forest biodiversity of Catalonia 2003-2011* (BIBOCAT), field tests of preliminary versions (2013-2016) and working in collaboration with national and international experts (2017). The final structure of the IBPC has been revised according to the IBP proposal published by the National Forest Ownership Centre of France (Larrieu & Gonin, 2012).

The biodiversity elements considered in the IBPC assessment are divided into two blocks: IBPC-Context and IBPC-Management. The IBPC-Context refers to intrinsic stand features, which can hardly be modified by forest management actions, while IBPC-Management parameters can be modified through the application of silvicultural techniques. Annex A1 describes in details the biodiversity indicators considered in the IBPC methodology.

The parameters considered in each block are:

- IBPC-Context. Landscape heterogeneity and presence of infrastructures, orography, historical continuity of the forest cover, presence of aquatic elements (nearby water points) and presence of rocky elements (rocky outcrops, large rocks or dry stone walls, among others).
- IBPC-Management. Vertical (vegetation stratification) and horizontal (gaps and ecotone spaces) structure, diversity of arboreal and shrub species, living trees with microhabitats (cavities, bark cracks, nests, mushrooms, wood without bark, fresh sap flow, dead branches, dendrotelms, fire or lightning scars, branched lianes, mistletoe and lichens), large living trees (DC45 or greater) and dead standing and lying large trees.

The IBPC assessment before and after the silvicultural interventions allows quantifying the stand changes with regard to its capacity to host biodiversity (Figure 16).

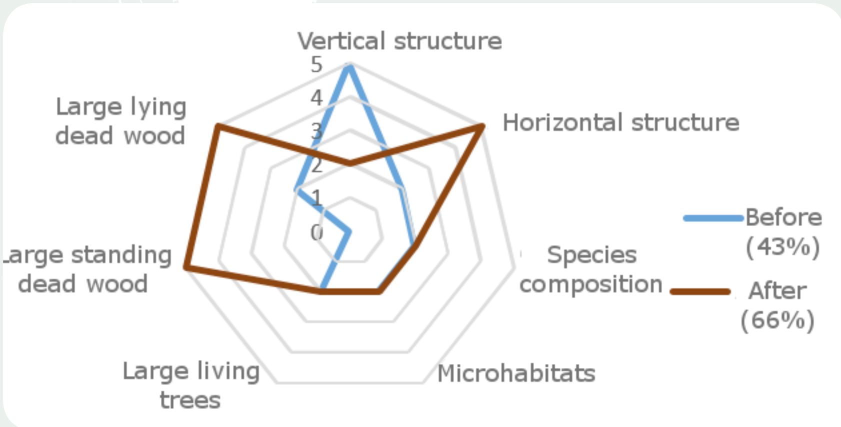


Figure 16. Example of IBPC assessment chart in a demonstrative stand of Life+ PINASSA, before (blue) and after (brown) the implementation of silvicultural treatments. There is an improvement in deadwood and horizontal structure and a loss of vertical structure (due to undergrowth clearing), while the other factors remain unchanged.

The elements of value considered in the IBPC are indirectly related to the specimens of interest that are or can be in the habitat, in function of its capacity to house them. For example, in the habitat of the black pine forests vascular flora species, mosses and lichens, mushrooms, night butterflies, saproxylic beetles, birds, bats and large mammals are considered of interest (Camprodon *et al.*, 2018). In any case, the evaluation of these particular specimens requires specific field inventory methodologies by expert staff (Table 2).

Table 2. Indicators or elements of biodiversity evaluated in black pine forests within the framework of the Life+ PINASSA project.

Indicator or element of biodiversity	Unit of Measure
Dead wood	Standing or lying deadwood in trees/ha or m^3/ha
Cavities and other microhabitats	IKA (kilometric abundance index) or cavities/ha
Flora of interest diversity	IKA
Abundance of species of flora of interest	IKA
Birds diversity	Number of species/listening site
Climbing birds	Individuals/listening site
Bats diversity	Number of species/night
Forest bats	Contacts/hour
Moths diversity	Number of species/night
Total moths	Contacts/hour
Soil fauna diversity	Number of taxonomic groups/trapping transect
Abundance of soil fauna	Individuals/trapping transect

3.2. Flora and fauna: endangered and of interest to the habitat

One of the elements of greatest biodiversity value is the endangered flora and fauna, which is especially diverse in the black pine forests habitat and whose preservation is fundamental.

In general terms, the specific richness and the abundance of specialist forest organisms (in ecological terms, *alpha diversity*) increases in the mature stages of succession. This affects species and functional guilds because they depend on the persistence over time of the tree cover that provides microclimatic stability with regard to temperature and humidity (mushrooms, lichens, bryophytes, nemoral phanerogams); as well as those taxons associated with variables of maturity such as old trees, deadwood, developed organic soils.

Flora

In Catalonia, the most relevant endangered flora species are those included in the Catalan catalogue of endangered flora (Resolution AAM/732/2015, Government of Catalonia) or described in the Red Book of endangered flora and special interest plants of Catalonia. These lists include those taxons which are of outstanding bio-geographical interest (they are endemic or rare at local or regional level) or that are characteristic according to the typology of the vegetation described for black pine forests. Species that can be good indicators of the forest structure and history of the stand are also included.

Flora that is endangered or has bio-geographical interest is generally associated to the existence of canopy discontinuities (gaps) and rocky outcrops, although exclusive forest species are also notable. In the areas of action of the Life+ PINASSA project, the most outstanding flora species (Figure 17) are the following:

- Southern Catalonia: *Taxus baccata, Ilex aquifolium, Ononis aragonensis, Paeonia officinalis subsp. microcarpa, Rosa pimpinellifolia, Epipactis atrorubens, Geum sylvaticum, Pyrola clorantha, Thalictrum tuberosum*.
- Central Catalonia: *Taxus baccata, Ilex aquifolium, Gentiana lutea, Dictamusalbus, Paeonia officinalis subsp. Macrocarpa, Ononis aragonensis, Lathyrus vernus, Clematis recta, Thalictrum tuberosum, Thalictrum minus, Prunus mahaleb, Rhamus alpina*.

Figure 17. Examples of the outstanding flora species of the habitat of the black pine forests. Up left, *Paeonia officinalis*. Up right, *Thymus willkomii*. Down left, *Ilex aquifolium*. Down right, *Viola willkomii*. Photos: David Guixé.

Regarding endemic and endangered taxons whose area of distribution is included within the demonstrative stands of the Life+ PINASSA project, Ports Natural Park (SAC Southern Pre coastal system) is the most relevant area, where 17 taxons have been documented or found during the inventories.

Among them, *Aquilegia paui*, *Arenaria conimbriscensis*, *Armeria fontqueri*, *Atropa baetica*, *Pinguicula grandiflora* subsp. *dertosensis* are endangered species in Catalonia, while *Biscutella laevigata* subsp. *fontqueri*, *Salix tarraconense* and *Thymus willkomii* are endemic to Ports area, *Euphorbia nevadensisbolosiis* are protected at European scale and *Ilex aquifolium*, *Paeonia officinalis* subsp. *microcarpa*, *Prunus prostrata*, *Saxifraga longifolia* var. *aitanica* and *Taxus baccata* are protected in Catalonia. On the other hand, *Sanicula europaea* and *Ranunculus gramineus* are rare species and *Viola willkommii* is characteristic of the habitat. In the SAC of Cardó-El Boix, the 3 most relevant species were: *Salix tarraconensis*, *Centaurea podospermifolia* and *Hieracium vinyasianum*, the second one being an endemism of Ports and neighbouring ranges and the third exclusive to Cardó range. In the northern stands the 3 most relevant species are *Rosa pimpinellifolia*, *Cephalanthera damasomium* and *Viola willkomii*, the first two being rare species not found in the southern stands.

Apart from endangered species, Annex A2 shows a list of some 100 relevant species elaborated following criteria of threat, endemicity, bio-geographic indicators, typical of the habitat or local interest that, according to contributions from scientific societies (SEBCP, CIBIO, AHE, SEO/BirdLife, SECEM), may be considered as typical of the habitat type of community interest 9530* of *Pinus nigra*. Those taxons that are relevant to maintain the habitat type in a favourable conservation status are considered **typical species**, either for their dominancy-frequency (structural value) and/or for the key influence of their activity in ecological functioning (functional value).

Fauna

Fauna that is endangered or of interest that can be found in the habitat of black pine that are in annex II of the Directive 92/43/CEE include: *Eriogaster catax*, *Graellsia isabelae*, *Callimorpha quadripunctaria*, *Lucanus cervus*, *Cerambyx cerdo*, *Barbastella barbastellus*, *Rhinolophus ferrumequinum*, *Myotis emarginatus*, *Myotis bechsteinii*.

Annex A3 shows a list of fauna species considered typical species of the habitat of black pine. Among them, *Myotis bechsteinii* is the most relevant because the first evidence of reproduction in Catalonia was found during the monitoring actions of Life+ PINASSA project (Figure 18).

Figure 18. Pregnant female of Bechstein bat (*Myotis bechsteinii*) found in monitoring sampling within the Life+ PINASSA project, which meant the first evidence of reproduction of this endangered species in Catalonia.

4.

Best practices to be integrated in black pine management

4. Best practices to be integrated in black pine management

4.1. Integration of conservation measures in forest management

The success of **making conservation and forest production compatible depends to a great extent in being able to integrate certain objectives and action in conventional silvicultural practice**, without a significant increment of costs or causing important limitations to forest operations and production.

> These conservation actions can be designed and executed exclusively to improve the elements of value for biodiversity or they can complement the actions of sustainable forest management with further objectives.

In this section we introduce **general recommendations of management for the conservation of the black pine habitat and specific actions to promote the elements of value for the biodiversity**. In any event, the objective is not to apply all of them at the same time, but to adapt their choice in accordance with the specific conditions of each stand. To do this, it is necessary to know in detail the characteristics of the forest to be intervened in relation to the existent elements of value, the state of development of the habitat, the current phase of the forest dynamics and management objectives, both at the level of the stand to intervene and of the whole property or management plan area.

The best practices for integrating conservation are applied in all phases of forest management, from the general planning at different levels (landscape, property, stand) to the implementation and monitoring of the interventions. However, the more decisive phases are the specific design of silvicultural interventions and their implementation.

> In general, conservation actions, be they specific or adaptations on generic silvicultural interventions, focus on maintaining existing elements of value and promoting or generating non-existent ones that are considered necessary, the regeneration or development of species of interest. Thus, the aim is to advance toward more mature and complex structures and promote areas of shelter, food or reproduction for certain species.

The general recommendation is to maintain and promote elements of value for biodiversity that are already in the forest (Figure 19), as long as they do not reach levels that compromise other functions or the safety of the silvicultural interventions or the use of forest roads and paths.

Figure 19. The removal of dead trees usually supposes a high cost, while its maintenance in the forest generates high value for biodiversity without compromising other functions. Photo: AGS-CTFC.

On the other hand, the application of **actions for the prevention of large forest fires** carried out in strategic areas to modify the behaviour of fire and facilitate its suppression can also be considered very important **for the conservation of the habitat**. This is an approach at landscape scale, where the prevention of fires on a specific area is improved by acting in a small part of it, considered strategic to change the behaviour of a great fire and where suppression can be developed with more effectiveness. These actions are based mainly on the generation and maintenance of forest structures of low vulnerability to high-intensity fires. Figure 20 shows the behaviour of fire before and after carrying out fire prevention treatments (selective clearing and low thinnings) in black pine forests (Piqué *et al.*, 2013).

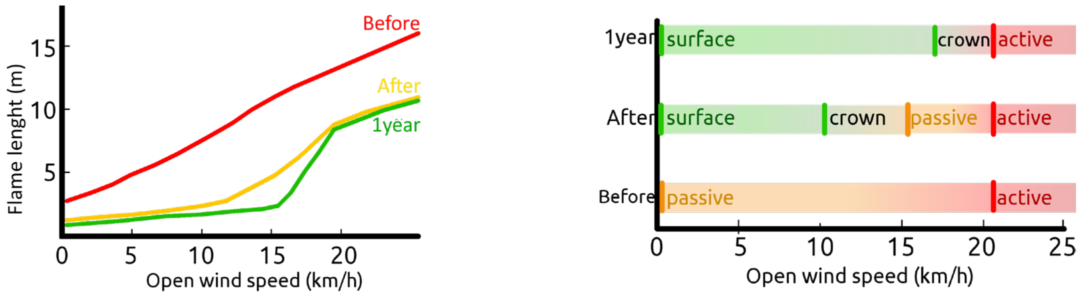


Figure 20. Example of results of the actions for the prevention of large wildfires in strategic areas. The simulations show that after the intervention it is expected a reduction of flame length and a change of fire type, from passive crowns fire to surface fire, for a range of wind speeds (Piqué *et al.*, 2013).

Lastly, in parallel to the actions for the maintenance and promotion of elements of value for biodiversity, it is also recommended considering **incorporating actions for the elimination of exotic species,** especially the invasive ones. Reducing the presence of these species improves the characteristics of the habitat with regard to its conservation status, but at the same time it is necessary to be conscious of the possible negative consequences of their elimination in the ecosystem. An example would be the risk of erosion resulting from the elimination of plantations done with protective purpose of black pine of other subspecies (*laricio*, *dalmatica*, *pallassiana*) in the Pre-Pyrenees and the southern Iberian System.

4. 2. General recommendations adapted to the types of black pine forests: application of the ORGEST management models

Although the implementation of silvicultural treatments is the most critical moment to integrate the conservation of the habitat, **the multi-functional approach of forest management must be considered since the planning stage**. To do this, it is recommended the use of decision support tools specifically designed for forest planning adapted to the forest types object of the management , like the *Guidelines for Sustainable Forest Management in Catalonia* (ORGEST). Although the ORGEST management models for black pine (Beltrán *et al.*, 2012) are optimized for specific preferred objectives (timber production, prevention of fires), they are conceived for multi-functional forest management, for which they are an ideal basis for integrating conservation measures.

Taking these ORGEST models as a basis, specific silvicultural interventions can be defined for a certain black pine stand, to which specific conservation actions would be added, based on sections 3 and 4 of this guide, to assure conservation and improvement of the habitat within multi-functional management.

In order to choose the most appropriate ORGEST management model for each case, it is recommended to carry out a complete inventory to define the forest typology, the fire risk and the preferred structure and objectives to accomplish. **In most situations it will be necessary to define some actions** to adapt the stands towards the ORGEST management models, for which it is recommended to follow the indications of the ORGEST manuals:

- To choose the management model that requires the smallest possible structural modification.
- To determine the intensity of the intervention based on the spacing and slenderness of the standing trees when the initial density is higher than that required in the model. The parameters of control are the basal area, the density and the Hart-Becking index.
- To start regeneration, or at least to carry out a last action to prepare trees for regeneration, when the trees show differences in density, basal area, mean diameter and other parameters, at an age or vital status that do not assure an adequate response to the silvicultural treatments aiming to improve the structure. In general, the main criteria to follow is the basal area to extract and to maintain after the intervention, always guaranteeing the stability of mother trees.
- To define the silvicultural intervention spatially-explicit when seeking to define an irregular structure in groups. The main objective is to achieve an occupation and density of the different size groups in a proportion similar to that of the reference model. In cuttings aiming to adapt the stands to a particular model, usually done as a mixed thinning (low and high), different communities of trees in different positions should be favoured to achieve the structure. Likewise, it is common the shortage of regeneration, so to create new gaps it should be taken advantage of incipiently open groups and areas with low vigour or poorly shaped trees.

Following the planning, silvicultural interventions are designed in function of the current characteristics of the forest and must therefore be adapted to the type of black pine forest. In the following sections, general recommendations are presented for the most frequent types of black pine forests, where the combination of objectives (production, conservation of habitat and prevention of forest fires) can be considered.

Relatively young and dense forests

The structures of relatively young and dense black pine forests, scarcely or not previously intervened are characterized by their sensitivity to strong canopy openings. They may have a dominant height close to 15 m and a basal area over 50 m^2/ha, with densities superior to 2,000 trees/ha, average diameter of up to 15 cm and average height over 11 m.

The trees conforming this type of structures have grown in high density resulting in good collective stability, but in turn, in low individual stability, with excessively slender trees. In these forests **it is recommended to plan frequent, low intensity thinnings to regulate the competition and promote tree growth** that may have been stagnated due to high density. Planning has as main indicator the Hart-Becking Index (it expresses the level of competence in function of the average distance between trees and their dominant height) and the basal area. Both parameters implicitly assume the control of density, which leads to the recommendation that **the first thinning should be of low intensity not to put in risk the collective stability**. In areas where spring snow can occur, it is even more important to maintain collective stability since this type of snowfall severely affects the canopy. In the forthcoming thinnings the intensity may progressively increase since the individual stability of the trees will improve.

The thinnings will consist of the regulation of the competition, eliminating trees from the lower layers so that the co-dominant trees will be the most benefited (Figure 21). The interventions should assure the collective stability, for which the indicators of stability are decisive for the definition of actions. Also, the broadleaved species present will be favoured, up to a maximum of 20% of the total basal area, and complementary actions to reduce the structural vulnerability to crown fires and other actions of habitat improvement will be carried out (See sections 4.3. and 4.4.).

Figure 21. Demonstrative stand of the Life+ PINASSA project, consisting of a relatively young and dense forest, after silvicultural intervention. In stands with trees of low individual stability, it is important to maintain good collective stability. Photo: CPF.

Adult forests without regeneration

The structures of adult black pine stands that are regularised and without regeneration, with a history of regressive interventions (negative selection), usually have problems of competition with other species and with shrubs when it is intended to generate and maintain new cohorts of pines. These stands generally have a dominant height around 18 m and a basal area of 30 to 50 m^2/ha, with densities ranging between 500 to 1,500 trees/ha, an average diameter of 20 to 30 cm and average height over 14 m.

It is recommended to plan intense interventions in the whole structure, especially in the dominated tree layer and scrub, to generate more favourable conditions for pine regeneration, especially by creating gaps and favouring illumination of the mother trees' crowns.

The problems of regeneration of the black pine, in the case of the *pyrenaica* variety, are usually due to the excessive competition of scrub with the seedlings, together with conditions of temperature and humidity of the soil and contact with the mineral soil. These factors are linked to the canopy and scrub cover and to soil compaction. The recommendation of management to resolve this problem is the **progressive canopy opening and the selective shrub clearing to increase the direct sunlight and wind circulation**, thus modifying soil temperature and humidity and in turn, the stirring of soil through logging operations.

In the case of the adult forests where previous interventions have not allowed the proper development of the phenotypically best trees, either due to negative tree selection or to excessive competition, it is recommended considering the application of **preparatory actions to begin regeneration,** as a starting point of a uniform or group shelterwood system leading to regular stands. This would imply the application of mixed thinnings where the development of the best trees' crowns is encouraged and the least interesting trees are eliminated (Figure 22).

Figure 22. Demonstrative stand of the Life+ PINASSA project corresponding to the typology of adult forest without regeneration, after silvicultural intervention. The necessary conditions are created to prepare the stand for regeneration in regularized structures, by reducing shrub cover and the generation of small canopy gaps, while the best trees are maintained. Photo: AGS-CTFC.

In the case of forests with strong development of the shrub layer and with a dominated tree layer mainly formed by Mediterranean oaks, that can hinder pine regeneration, it is recommended applying a coppice with standards to the oak stratum and releasing the competition to all the black pine specimens. Moreover, if other pine species are present (Scots or Aleppo pine) it should be assessed whether these species should be prioritized to be cut over the black pine bearing in mind the micro-site conditions where they occur. In the spaces where the black pine is dominant, the treatment should be planned in function of their current state, not advancing the regeneration if the trees are not sufficiently adult since this would lead the stand toward a semi-regular or irregular structure, which in this case is not the desired structure.

The interventions would consist in the preparation of the stand for hosting regeneration, reducing the density and creating canopy gaps adapted to the species temperament. This would be the first phase (preparatory cuttings) of a shelterwood cutting, which should be adjusted to the conditions of each stand, taking advantage of advanced regeneration wherever existent, not extracting more than 40% of basal area. In addition, these actions should reduce the stand structural vulnerability to crown fire, together with other actions of habitat and biodiversity improvement.

Irregularized forests with limited regeneration

The black pine forests with irregular structures, often understocked and with poor regeneration, with a record of regressive interventions with negative tree selection, usually present imbalances regarding the proportion of trees from the different functional groups of trees: regeneration, active growing and maturity. This usually results in a regeneration that is heterogeneous and discontinuous over time so that the irregular structure is not stable. These stands generally have a total basal area of 25 to 40 m^2/ha, where the group of medium size (diameter classes 20 to 30) is abundant, around 60% of basal area, and the smaller and larger sizes are underrepresented. The density vary from 700 to 1,400 trees/ha, with an average diameter around 16 cm and an average height over 11 m.

In good sites these forests can evolve toward capitalization and regularization, while in most cases they continue having stagnant growth and lack of regeneration, leading to an aged and understocked stand where the shrub layer and other tree species proliferate (Mediterranean oaks, Aleppo pine).

The traditional selective thinning carried out in black pine forests have led to structures considered as irregular forests, although **in many occasions these silvicultural interventions did not include stand improvement criteria** to extract the trees that are less vital or show poor characteristics. The resulting stands have a high density of young trees, scarce regeneration and a high proportion of trees with poor phenotypic conditions.

To solve this situation it is recommended to **encourage an irregular structure opening small gaps** (from a single tree to 1,000 m^2), adjusting the percentage of basal area of each size group according to the values of the reference model (Figure 23). This intervention requires detailed knowledge of the stand and a precise planning. **This process must be accompanied by an accurate implementation of the interventions.**

It is recommended to consider low-intensity actions in the whole stand, including the dominated tree layers and the undergrowth, to generate more favourable conditions to progressively start the regeneration and favour the development of the adult trees, always aiming at the continuous regeneration by patches.

These actions consist of selective thinnings to eliminate deficient and low-vigour individuals and those competing with the most vital trees. Moreover, in areas where the current structure is very different from the reference model, mixed thinnings should be applied to balance the proportion of the different group sizes that result in an irregular stand. If necessary, canopy gaps of less than 1,000 m^2 could be opened, generating regeneration cones adequate to the species. These actions should also redistribute the size groups over the space, by patches of less than 1,000 m^2, and to regulate the proportion of each size group within the stand, according to the reference management model addressed. Also, specific actions for habitat and biodiversity improvement should be considered.

Figure 23. Demonstrative stand of the Life+ PINASSA project corresponding to the typology of an irregularized forest, after the silvicultural intervention. Actions are focused on achieving an irregular structure by groups, adapted to the species temperament, with a heterogeneous intensity within the stand. Photo: AGS-CTFC.

Stands with the preferred objective of large forest fires prevention

In stands located in strategic points for the prevention of large forest fires, the fire prevention objective prevails over others such as production or biodiversity enhancement. The dasometric parameters of these stands can be very variable, because **the main factor that determines this management objective is its localization in a strategic point** and, moreover, the action is designed based on structural parameters. The stands with a high vulnerability to crown fires are those with vertical and horizontal continuities of fuel layers. These stands are often regularized, with a basal area close to 30 m^2/ha, densities of 700 to 1,800 trees/ha and an average height lower than 10 m.

In large fires prevention actions, it is necessary to identify two scales of planning. On the one hand, the localization of the actions to maximize their efficiency and, on the other, the specific silvicultural intervention to minimize the vulnerability of the stand to crown fires.

The first part must be approached with planning figures at landscape scale, based on all the available context information to localize the actions for large forest fires prevention, as well as the types of fires affecting the area and their pattern of propagation.

The second part refers to the management models with the preferred objective of fire prevention, where **the most relevant management parameters are those related to the stand structure**. The interventions are designed considering stand structure and its vulnerability to crown fire, leaving as secondary variables like density, basal area or average diameter. In any event, the ORGEST management models for forest fire prevention also incorporate criteria for the regulation of arboreal competition and related with regeneration.

The interventions would consist of the elimination (either mechanical or with prescribed burning) of part of the vegetation in the different fuel layers in the proportions specified so as to create vertical discontinuity leading to a less vulnerable structure. Actions of habitat and biodiversity enhancement can also be carried out (Figure 24).

Figure 24. Demonstrative stand of the Life+ PINASSA project corresponding to the case of stands located in strategic points for the prevention of large forest fires, after the silvicultural intervention. The interventions aims to the stratification of the vegetation (horizontal cover and distance between vertical layers), to achieve a structure of low vulnerability to generate and maintain active crown fires. In general, it is intended to break the continuity of the undergrowth and the canopy layers, and to advance in the maturity of the forest with large trees resistant to the passage of fires. Occasionally elements of value for biodiversity like some lying dead trees may be maintained.

4.3. Specific actions to encourage elements of value for biodiversity

Once that the reference ORGEST management model and the silvicultural treatments to apply are chosen, it is necessary to define the actions to promote elements of biological value. The main actions with this regard are:

- Selection and maintenance of trees of interest (large size, with cavities and other microhabitats).
- Generation of dead wood of different types.
- Selective clearing of the undergrowth, keeping in mind the different species.
- The management of slashes and other vegetation residues.

The type and quantity of elements of value to maintain or generate will depend on the characteristics of the treated stand and on the management objectives.

In young stands it is possible to achieve a favourable structure for hosting biodiversity gradually over time, with several consecutive actions. In adult stands where the previous interventions have hindered the existence of microhabitats, it is possible to achieve a more favourable structure for biodiversity, but always thinking of long-term dynamics than on the current stand itself, since this it is on the way to regeneration.

In any case, it is necessary to use a vision at forest or landscape scale, since the lack of maturity and of elements of interest for biodiversity in a given stand can be present in an adjacent one.

Selection and maintenance of trees of interest

The trees of interest are those containing microhabitats, belonging to a species different to the main ones or having singular characteristics. It is also possible to leave some trees of the main species to reach or approach their limit of longevity. The objective is to have sufficient variety and quantity of microhabitats to house different communities of fauna and a diversity of arboreal species of botanic interest.

The number of trees of interest to maintain in the stand depends on several factors, both intrinsic to the stand and related to the surrounding areas, thus being difficult to establish a specific number. Generally, in black pine forests where the objective of habitat conservation are combined with others like forest production, **the tentative number of trees of interest can be up to 3-5% of the trees in young forests and up to 40 trees/ha in adult forests.** All the living trees of interest for different reasons are considered within this quantity.

To guarantee the presence of enough trees of interest, starting out from those already existent in the stand, the following trees are conserved during silvicultural actions:

- Living trees with woodpecker cavities, with platforms of nests of interest for birds of prey, adult pines with forked trunks above 4 m of height, crooked trees growing on rocks and in general living trees carrying microhabitats (see section 3) (Figure 25).
- Tree species accompanying the black pine, especially broadleaved species and those producing fruit, ideally distributed irregularly in the stand. In general, it is recommended that this group of trees should not represent more than 20% of the basal area, of all the species not belonging to the main stand (black pine in pure stands and this and secondary species in mixed stands).
- Trees of any species showing singular phenotypic characteristics or that are significantly bigger than the rest, if they have not been considered in the previous groups. If there are several trees of this type, the total number of trees of interest to maintain can be increased up to 50 trees/ha in adult forests, and it includes trees that should remain in the stand indefinitely, individually or in groups of 4-6 trees.

In case that the number of living trees carrying microhabitats is low, it is possible to choose and promote some trees that could potentially develop microhabitats in the short term, for example, trees with large dead branches or unbalanced crowns that can break. Tentatively some 10-15 trees/ha of this type can be selected.

Figure 25. In the black pine forests of the Pre-Pyrenees it is common to find specimens of oak from the time when the area was open pasture. Nowadays these trees are excellent carriers of microhabitats. Photo: AGS-CTFC.

Deadwood generation

Dead trees can be found in different forms and phases of the decomposition dynamics. Each type of deadwood can be of interest for different species, so that it is recommended promoting and maintaining this resource in various forms.

As in the case of living trees of interest, the total quantity of deadwood to maintain in the stand depends on many factors and its estimation is complex. **The general recommendation in the case of adult forests, would be to keep up to 20-30 trees/ha of dead trees in different states of decomposition, considering both standing and lying individuals**. In young forests it is not a priority to have large quantities of deadwood so it is recommended keeping what already exists, what is generated naturally and, if considered necessary, progressively generating more in successive silvicultural interventions.

To guarantee the presence of deadwood in the stand, starting with the preexisting one, the following recommendations are done for the silvicultural interventions:

- Mantenir tota la fusta morta ja present, de diferents tipus, fins als llindars de quantitat de referència marcats.
- Maintain all deadwood of different types already present, until reaching the thresholds of reference.
- Devitalize trees and generate deadwood if necessary, by girdling or radial cutting the outer part of the trunk that distributes nutrients, without affecting the inner part with structural function. The trees to girdle should show high individual stability, thick diameter (at least 20 cm) with a bole height of at least 4 m.
- Fell and leave on the ground without lopping trees with diameter of at least 15 cm, also leaving a 40-50 cm high stump.
- During tree felling in thinnings, leave 40-50 cm high stumps, prioritizing those with curved base. These logs make stacking, transport and timber processing difficult. These curved stumps can be left at heights

of more than 50 cm. The total number of high stumps to leave can reach about 10 - 15 stumps/ha, complementary to the rest of deadwood elements.

When generating deadwood during the silvicultural interventions it is necessary to keep in mind the following factors:

- Girdled trees should be protected by the crowns of adjacent trees to maintain their stability.
- The possible fall of these trees must not affect forest tracks, paths or other elements of interest.
- Girdled trees should have a structure that guarantees their stability during the longest possible time, avoiding, if possible, selecting trees with good potential for timber production.
- It is recommended that the distribution of girdled trees in the stand and those already dead or dying is homogeneous. However, it is also interesting to create groups of 3 -5 of these trees in some 1,000 m^2 to increase the probability that they produce a surplus of cavities for bats and other fauna.
- The generation of deadwood must be carried out in various phases or interventions to ensure the continuous provision of a resource that decomposes over the years as well as to guarantee the presence of trees in different phases of decay and decomposition.
- The felled trees left on the ground should be at least 20 m away from main forest roads, not hindering logging operations and being distributed homogeneously.
- High stumps should not hinder logging, skidding and hauling operations.

The purpose of girdling trees is to kill them standing for the benefit of fauna like birds or bats, especially as a shelter. Thus, in adult black pine forests where standing dead trees are scarce or absent, it is advisable to install specific nest boxes. This is a transitory measure to encourage bird breeding of species requiring cavities and the establishment of colonies of bats, during the time required to have natural cavities generated (Figure 26).

Annex A4 shows a summary of actions carried out in the framework of the Life+ PINASSA project to generate dead wood. The quantity of deadwood generated in each stand varies considerably in function of multiple factors like initial stand conditions (maturity, tree size, available standing and lying deadwood), management objectives and the interest of the forest owner. Consequently, although reference values of up to 20-30 trees/ha are proposed, in most cases this number was not reached. However, in all cases the deadwood is kept (Figure 27) or increased (Figure 28) with the interventions carried out, as a starting point in the integration of biodiversity conservation measures in forest management and, in short, in making compatible forest production and the conservation of the black pine habitat.

Figure 26. Nesting box specifically designed for bats, installed in a demonstrative stand of the Life+ PINASSA project. Photo: Jordi Bas.

Figure 27. Dead tree in advanced decomposition status with natural cavities already existent, kept in the forest during the silvicultural interventions in a demonstrative stand of the Life+ PINASSA project. Photo: CPF.

Figure 28. New elements of deadwood generated during silvicultural interventions in demonstrative stands of the Life+ PINASSA project. Left, high stump. Right, girdled black pine. Photos: Jordi Bas.

Selective undergrowth clearing

The management of the shrub layer is decisive for directing certain phases of forest dynamics (mainly the establishment and development of regeneration), to define the forest structure with regard to risk factors (fires) and occasionally to favour particular species of fauna and flora of special interest, which can be outcompeted by species with a wide distribution.

Clearing the undergrowth allows regulating its competition with tree regeneration, opening spaces for its establishment, favouring certain shrub species with biodiversity value (providing fruit or shelter) and modifying the vertical and horizontal structure of the fuel layer to reduce the vulnerability to fires. In general, clearing does not include tree species, except for those showing a shrub-like behaviour, being part of this layer and not having a clear tendency to develop toward the arboreal layer, as it could be the case of Mediterranean oaks under black pine canopy.

The design of the undergrowth selective clearing must be adapted to the management objectives, with regard to the target shrubs to eliminate or promote, considering their height, composition, vitality and the final cover. Thus, the complete undergrowth clearing will be avoided since it implies a high-intensity intervention that can harm some forest functions or biodiversity (Figure 29). The planning of the undergrowth selective clearing requires:

- To determine the final undergrowth cover to maintain in the stand based on the characteristics of the shrub layer and management objectives. This target cover ranges from a minimum of 15-20% up to a total cover, which can be considered if there is a discontinuity of at least 4 m between the undergrowth layer and the base of the trees' crowns in areas of high risk of forest fires (Piqué *et al.*, 2011). In any case, the final undergrowth cover should be organized in small groups separated horizontally between them and, if possible, vertically with the trees' crowns.
- To define the target average height of the undergrowth layer. This height refers to the general undergrowth layer, even when individual or small groups of shrubs can be maintained with larger heights. Both the undergrowth average height and the cover are factors directly related to the structural vulnerability to fires.
- To define the type of elements of the undergrowth to be preferably maintained, respecting the target values of cover and height. This choice will depend on the stand characteristics and the management objectives, which can include the promotion of certain species, for example. In general, the shrubs to maintain are those of species that are protected, have bio-geographic interest, produce fruit for fauna or are underrepresented, as well as those species with a poor growth potential so that the vertical fuel discontinuity created is not lost in the short term.

In certain areas it is common to cut the ivies growing on the trees, especially during undergrowth clearing. On the one hand, large ivies can act as ladder fuel for the fires, thus increasing the stand vulnerability. However, ivies of large dimensions are an element of value for biodiversity as providing shelter and food to fauna. Therefore, specific instructions with regard to the ivies should be considered in the design of the clearing. In general, it is recommended to preserve them when possible, at least the largest ones, as long as the structural vulnerability to forest fires is not compromised.

Figure 29. Selective undergrowth clearing with chainsaw and brush cutter carried out in a demonstrative stand of the Life+ PINASSA project.Photos: Jordi Bas.

Management of slashes and other vegetation residues

The vegetation residues generated during the operations of logging and shrub clearing have an outstanding role in factors like the stand structural vulnerability to fires, the soil microclimatic conditions, the black pine regeneration and the availability of shelter for fauna (birds, small mammals, reptiles, insects, etc.). Therefore the treatment of these residues must be considered in line with the forest management objectives. Obviously, those trees felled specifically to generate lying dead wood are not considered as logging residues to treat, although they must be kept in mind when evaluating the cover of surface fuel. In any event, this operation must respect the legislation related to forest fire prevention.

The objective of slash management is to avoid negative impacts in the forest functions, always seeking economic efficiency. Thus, the design of this operation consists of defining the total cover and the distribution and maximum height of accumulated residues in function of the stand characteristics.

In general, if there are no additional restrictions, it is recommended not leaving woody remains with diameter larger than 5 cm in pieces larger than 1 m long and avoiding accumulations of more than 50 cm in height, being distributed as homogeneously as possible (Figure 30). The banks or areas adjacent to rivers or water courses, pools, springs and any other flood-prone areas should be free of residues.

In certain cases, it may be necessary to move the slashes or to reduce their volume by chipping or shredding. For example, in the case that the residues generate a high or continuous layer of surface fuel, particularly in structures without vertical discontinuity (low crown bases), it is recommended chipping part of the residues and, if necessary, moving the unshredded remains of branches and shrubs to adjacent areas where the base of the crowns is higher. The movement of crown logging residues is advisable in silvicultural operations aiming at encouraging regeneration, to promote seed dispersion and facilitating their contact with the mineral soil.

Additionally, the slashes can be used to mitigate the impact of the machinery in the soil, for example placing them in haul roads and in areas susceptible to suffer compaction (Figure 31), as well as to avoid the erosion of the forest roads.

Figure 30. The management of slashes and shrub residues is part of the silvicultural operations, and in the interventions of the Life+ PINASSA project, they have been designed specifically for each stand. Photo: Jordi Bas.

Figure 31. Demonstrative stand intervened during the Life+ PINASSA project, where the residues of thinning and undergrowth clearing were placed along the haul roads to reduce the impact of soil compaction. One year after the intervention the road is barely noticeable. Photo: Mario Beltrán.

4. 4. Practical recommendations to make the integration of conservation measures effective

To accomplish the objectives established the interventions must be implemented carefully, which makes essential a proper transfer and communication with the staff executing them. This transfer should focus on practical aspects of implementation, even when the broad objectives and rationale of the interventions should also be explained. During the implementation of the demonstrative interventions of the Life+ PINASSA project, it was found that investing some time doing a basic training on specific practices that may be innovative is helpful for their correct implementation. To transfer efficiently some of the measures proposed in the project it is recommended:

- To mark the interventions whose implementation is variable throughout the stand, such as selection system, selective thinning and mixed thinning, and those for which the selection of the trees to preserve requires considerable technical evaluation. The marking should be done efficiently, either, in the whole stand or in a representative part.
- To mark singular trees to be kept during the interventions, as well as those selected to generate standing or lying deadwood, so that the personnel carrying out the cuttings do not have to choose them. In any case it is necessary to explain the workers the technical justification of this selection and the importance of assuring their maintenance in the forest. These singular trees must be respected even if it implies felling further trees not initially planned to ease (Figure 32).

Figure 32. The trees of special interest (carrying microhabitats or dead standing) can be marked with a permanent system. This picture shows a label shaped as a bat to indicate a singular tree (seen in black pine forests of Corse). Photo: Jordi Camprodon.

- In the case of cutting in an area that had been previously marked, it should be explained to the workers the meaning of all the marks used, which should be clearly differentiable.
- In cleanings and thinnings performed in dense forests it is essential to assure a final density that does not compromise the collective stability, for which an average distance between the trees to maintain must be established, as a reference of the final density.
- In thinnings of young and adult regularized forests, it should be stressed to the workers that the collective stability of the forest is achieved by maintaining the tangency of the tree crowns, especially when girdling trees to die standing.
- In adult forests with lack of regeneration it is capital to identify the mother trees that are intended to regenerate the area. Therefore, even when the complete intervention is marked, it is recommended explaining the workers the basic criteria of selection of these trees, that are those having a developed and balanced crown. Thus, in the event of having to fell additional trees to those marked, the workers will consider this criterion.
- In irregular forests whose structuration should be improved, a detailed planning should be done to define the groups of trees targeted and the intensity of the intervention (% basal area to remove), since these interventions have an explicit spatial component that is only specified when they are executed.
- In selective undergrowth clearings with a target final cover, it should be indicated to the workers that the groups respected must be separated one from another, prioritizing those located in open areas. It is also necessary to rank the species according to their priority for being maintained and ensuring that the workers know how to identify each species, even with vegetal samples if needed. It should be stressed that the undergrowth shorter than 1.3 m (breast height) should be respected unless specified explicitly. Moreover, undergrowth clearing must be made at ground level.
- When the intervention includes the generation of high stumps it should be remarked to the workers that, besides the spacing criteria, felling and logging operations should not be hindered. Thus, the high stumps must not be located in haul roads or skidding areas, and should be preferably chosen on trees that are particularly difficult to cut at the base (located in margins, having rocks or other elements adjacent to the trunk base), as well as those curved at the base that would challenge the tasks of stacking and transport (Figure 33).

Figure 33. Accumulation of logs in the access road after logging with cable and tractor in a demonstrative stand intervened during the Life+ PINASSA project. Photo: Jordi Bas.

All management interventions within black pine forests **must be executed following the principles of best silvicultural practices** and always complying with the legislation. We provide below two of the most relevant aspects for assuring the correct implementation of management interventions. Additionally, Annex A5 shows **a range of technical conditions of implementation** of forest management in black pine forests complementing the principles of best silvicultural practices.

Marking before implementing the interventions

A total or partial marking allows increasing the efficiency of the silvicultural interventions. The decision of whether to cut or to preserve a tree requires reflection based on the management objectives, stand and tree characteristics and also of the logistics of the felling and logging. This is why previous marking allows increasing the productivity of operators, as they can focus only on felling trees without damaging the trees to be maintained. An excess of information to carry out their work safely may result in a reduction of its quality.

Previous marking by specialized personnel is especially advisable for the selection of singular trees to be kept and for choosing those trees targeted to generate standing and lying deadwood, because the operators executing the interventions may not have training or previous experience in these tasks. On the other hand, for silvicultural operations applied at the whole stand level, tree by tree marking by specialized personnel is recommended in interventions where qualitative parameters (sociology, vitality, structures of crowns) of the trees to be kept are more decisive that the quantitative ones (spacing, diameter).

During the marking, besides the evaluation of management objectives and tree parameters, it is also necessary to consider how the felling and logging will be carried out, including the possible haul paths and the difficulties posed by rocks and trees hidering felling or logging, felling directions and potentially affected trees. Thus, the work of the logging operators becomes easier.

In general, marking of silvicultural interventions at whole stand level by specialized personnel has an estimated average productivity of 2 ha/day per person. This productivity depends to a great extent on the stand walkability, since it is necessary to evaluate all trees and mark those selected (Figure 34). An additional dedication of 20% time should be added when the marking of singular trees and that of trees to generate deadwood is done together with that of the silvicultural intervention. If only a marking of singular trees and of trees to generate deadwood is carried out, the average productivity would be around 4-6 ha/day per person, depending on stand walkability (Figure 35).

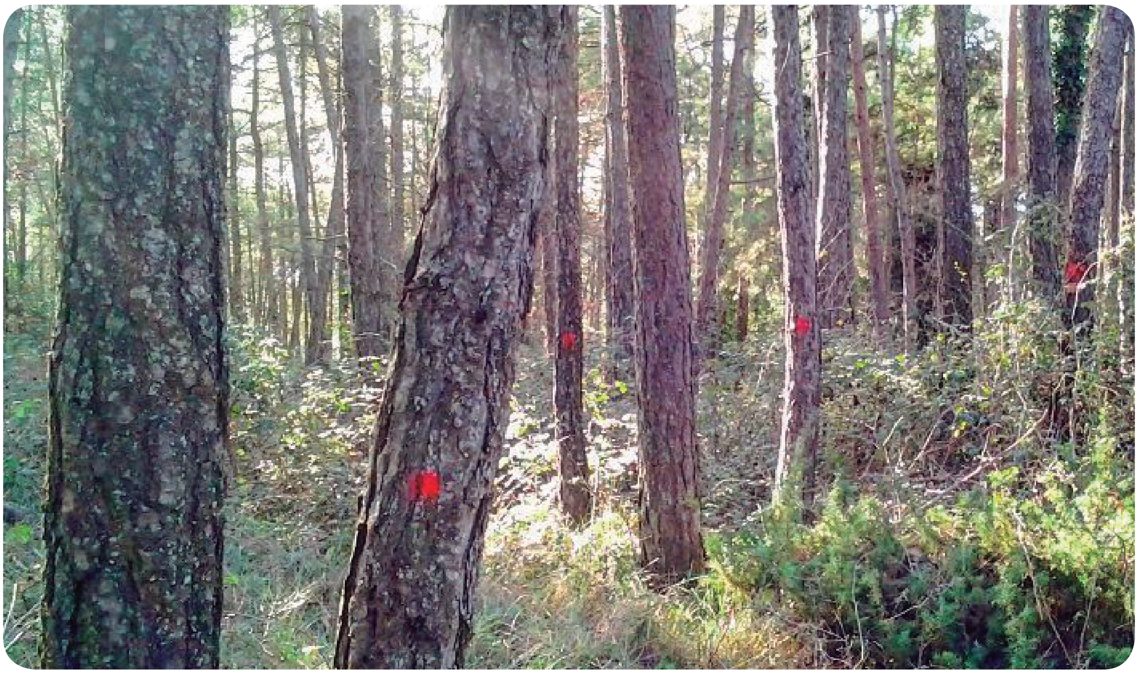


Figure 34. Demonstrative stand intervened during the Life+ PINASSA project where all the trees to cut were marked with a red dot at both the upslope and the downslope directions. Photo: AGS-CTFC.

Figure 35. Special mark to indicate that the tree must be girdled to generate standing deadwood, in a demonstrative stand of Life+ PINASSA project. Photo: Bio-CTFC.

Qualification of the personnel implementing the interventions

The qualification and training of the personnel implementing the interventions helps achieving their correct application and, therefore, assuring management objectives including conservation of the habitat (Figure 36). The implementation of forest interventions can generate certain negative impacts in the environment that can be minimized by a correct implementation, so qualification and training of personnel is an indirect measure of habitat conservation.

It is therefore advisable that all operating personnel have the best training and qualification possible. An adequate system of reference is the certification of competences promoted by the *European forestry and environmental skills Council*, with the European Chain Saw Operator Certificate as the main qualification.

Figure 36. Logs heaped in the upper part of the haul road using maintained trees to hold them, in a demonstrative stand of an intervention of the Life+ PINASSA project. Photo: Jarkov Reverté.

5.

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5. Bibliographical references

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Annexes

Annexes

A1. Index of Potential forest Biodiversity of Catalonia

As described in section 3 of this guide, the Forest Ownership Centre of Catalonia has recently developed an Index of Potential Biodiversity of Catalonia (IBPC) that can be useful for evaluating the conservation of biodiversity in the black pine forests (Baiges *et al.*, 2018).

To assess the factors considered in the IBPC it is necessary to cover the whole of the stand evaluated, since some factors are referenced over the whole area, as well as to carry out a transect inventory calculating the sampled area, since some factors are referenced by hectare. The sampling by transects proposed can be:

- Total transect in stands of up to 4 ha. The sampling area coincides with that of the stand.
- Partial transect in stands of more than 4 ha. It is necessary to sample at least 15% of the stand area and a minimum of one hectare.

The tables below show the indicators considered in the IBPC, the measurement unit and the level for considering the indicator as unfavourable, favourable and optimum.

IBPC Context Block				
Indicator	**Unit of measure**	**Unfavourable Case**	**Favourable Case**	**Optimum Case**
Landscape structure (in 1 km radius)	Factor	Abundant infrastructures	Continuous landscape (forest stands)	Mosaic of forest structures and open spaces
Relief and orography (in 1 km radius)	Factor	Flat and homogeneous	Limited heterogeneity, small variations	High heterogeneity, relevant variations
Temporal forest continuity	Factor	Recent forest, established later than 1950s	Forest from early XX century	Forest previous to the XX century
Water elements (within or near the stand):	Nombre d'elements	Cap element aquàtic	Un element aquàtic	Dos elements aquàtics o més
Rocky elements of >20 m^2 (within or near the stand): slabs and caves, rock accumulations, dry walls, rocky outcrops and large rocks	Number of elements	No rocky elements	One rocky element	Two or more rocky elements

IBPC Management Block				
Indicator	**Unit of measure**	**Unfavourable case**	**Favourable Case**	**Optimum Case**
Vertical structure of layers with cover >20%: canopy, dominated layer, and undergrowth	Number of layers	One layer	Two layers	Three layers
Open spaces (gaps) and edge ecotones (stand perimeter)	Percentage of the stand area	No open spaces or ecotones	Less than 1% or more than 5% of the stand	Between 1% and 5% of the stand
Composition and diversity of the layers: species present, fruit producers or exotic invasive species	Composition and number of species of each type	Pure stand or presence of exotic invasive species	Mixed or pure stand with two accompanying tree species	Presence of 5 or more tree species or the previous situation with a significant presence of fruit producing species
Living trees carrying microhabitats (maximum 2 trees/ha of each type of microhabitat: - Cavity of birds (≥4 cm) - Stump cavities (≥10 cm) - Wood without bark (not rotten) (>600 cm2) - Evolving cavities in trunk or branches (≥10 cm) - Dendrotelms (≥15 cm) - Wounds of lightning bolt or fire - Cracks or detached bark (shelters) - Fungus and cankers (≥10 cm) - Fresh flow of sap or resin - Deadwood in the crown (>20%; or D ≥15 c ad, L ≥50 cm) - Nests and platforms - Lianes, lichens or mistletoe (>25%)	Density per hectare in the stand	Less than 1 microhabitat/ha	Between 1 and 5 microhabitats/ha	6 microhabitats/ha or more
Large living trees (diameter class 45 or higher)	Density per hectare in the stand	Less than 1 tree/ ha	Between 1 and 4 trees/ha	5 trees/ha or more
Large standing deadwood: whole trees, stakes and stumps of L≥1 m and D≥25 cm	Density per hectare in the stand	Less than 1 tree/ha	Between 1 and 2 trees/ha	3 trees/ha or more
Large lying deadwood: trunks of L ≥1 m and D ≥25 cm	Density per hectare in the stand	Less than 1 trunk/ha	Between 1 and 2 trunks/ha	3 trunks/ha or more

A2. List of species of flora considered typical of the black pine habitat, their threat level and priority of conservation

Species	Main Habitat	Rarity	Location	Threat Category	Conservation interest	Priority of conservation	Family
Aquilegia paui	Rocks and shady pasture lands	rrr	Ports	EN	Ports Endemism	1	Ranunculaceae
Aquilegia viscosa montsicciana	Rocks, scrubs and dry pasture lands	rr	Central Pre-Pyrenees		Rare	2	Ranunculaceae
Arenaria conimbricensis	Open forests and gaps		Ports		Southern mountains Endemism	2	Caryophyllaceae
Armeria fontqueri	Rocks, scrubs and dry pasture lands	rr	Ports	VU	Protected in Catalonia and Ports Endemism	1	Plumbaginaceae
Aster willkommii subsp. catalaunicus	Forest		Ports		Protected Catalonia	2	Asteraceae
Atropa baetica	Open forests, gaps, scrub and rocks	rrr	Ports	EN	Protected Europe	1	Solanaceae
Atropa belladona	Forest	r	Montserrat		Rare	3	Solanaceae
Berberis vulgaris subsp. *seroi*	Gaps and scrubs	rr	Ports	VU	Protected Catalonia	1	Berberidaceae
Biscutella laevigata cuneata cardonica	Forest	r	Ports		Rare	3	Cruciferae
Biscutella laevigata subsp. *cuneata*	Rocks, scrub, gaps	c	Ports		Ports Endemism	2	Cruciferae
Campanula persicifolia	Forest	r	Pre-Pyrenees central, Montserrat		Rare	3	Campanulaceae
Campanula speciosa beltranii	Forest		Ports		Ports Endemism	2	Campanulaceae
Centaurea boissieri spachii /mariolensis	Gaps and dry scrubs		Ports		Ports Endemism	2	Asteraceae
Centaurea jacea dracunculifolia	Pasture lands		Ports		Ports Endemism	2	Asteraceae
Centaurea loscosii	Rocks and gaps	rr	Ports	VU	Ports Endemism	1	Asteraceae
Centaurea podospermifolia	Rocks and gaps	rr	Ports	VU	Protected in Catalonia and Ports and Cardó Endemism	1	Asteraceae
Centranthus angustifolius lecoqii	Rocks		Ports		Ports Endemism	2	Valerianaceae
Cephalanthera damasomium	Forest	r	Central Pre-Pyrenees		Rare	3	Orchidaceae
Cephalanthera longifolia	Forest		General		Biogeographic interest.	3	Orchidaceae
Cephalanthera rubra	Forest		General		Biogeographic interest	3	Orchidaceae
Clematis recta	Forest	r	Pre-Pyrenees and central Pyrenees		Protected Catalonia	2	Ranunculaceae
Cotoneaster integerrimus	Forest		Ports		Protected Catalonia	2	Rosaceae
Cotulea arborescens	Forest	r	Central Pre-Pyrenees, Montserrat		Rare	3	Papilionaceae
Dianthus multiceps	Forest		Pre-Pyrenees		Pre-Pyrenees Endemism	2	Caryophyllaceae
Dictamus albus	Gaps and forest edges	rrr	Central Pre-Pyrenees		Rare	1	Rutaceae

Species	Main Habitat	Rarity	Location	Threat Category	Conservation interest	Priority of conservation	Family
Digitalis lutea	Forest	r	Central Pre-Pyrenees		Rare	3	Scrophulariaceae
Digitalis obscura	Forest	r	Ports		Rare	3	Scrophulariaceae
Dryopteris villarii (= D. mindshelkensis)	Shady Rocks	rr	Ports	VU	Protected Catalonia	1	Polipodiaceae
Epipactis atrorubens	Forest	r	Ports		Rare	3	Orchidaceae
Erodium foetidum subsp. *celtibericum*	Rocks, scrubs and dry pasture lands	rr	Ports	VU	Ports Ende-mism	1	Geraniaceae
Erysimum grandi-florum subsp. *collis-parsum*	Forest	r	Central Pre-Pyrenees		Rare	3	Cruciferae
Euphorbia nevadensis bolosii	Scrub, dry pasture and rocks		Ports		Rare and pro-tected Europe	2	Euphorbiaceae
Euphorbia nicaensis	Forest	r	Ports			3	Euphorbiaceae
Ferula loscosii	Dry pasture lands	rr	Ports	VU	Protected Catalonia	1	Umbelliferous
Fritillaria pyrenaica subsp. *boissieri*	Rocks and dry pasture lands	rr	Ports, Pre coastal System		Rare	2	Liliaceae
Galatella aragonensis	Gaps and forest edges	rr	Ports	VU	Protected Catalonia	1	Asteraceae
Genista patens	Forest	r	Pre coastal System		Rare	3	Papilionaceae
Gentiana lutea	Forest	r	Ports, central Pre-Pyrenees		Rare	3	Gencianaceae
Geum sylvaticum	Forest	r	Ports		Protected Ports	2	Rosaceae
Gymnadenia conop-sea	Forest	r	Central Pre-Pyrenees		Rare	3	Orchidaceae
Helianthemum origa-nifolium molle	Forest		Ports		Ports Ende-mism	2	Cistaceae
Hieracium solidagi-neum	Rocks and open-forests	r	Ports		Protected in Catalonia and Cardó ende-mism	3	Asteraceae
Hieracium vinya-sianum	Shady Rocks	rrr	Pre coastal System		Cardó Ende-mism	1	Asteraceae
Ilex aquifolium	Forest		General		Protected Catalonia	2	Aquifoliaceae
Knautia arvensis rupicola	Forest		Ports		Ports Ende-mism	2	Dipsacaceae
Lathyrus filiformis	Forest	r	Central Pre-Pyrenees		Rare	3	Papilionaceae
Lathyrus vernus subsp. *vernus*	Humid forests	rr	Central Pyre-nees		Rare (Pyre-nees)	2	Papilionaceae
Leontodon crispus	Forests	rr	pre coastal System	VU	Llaberia Ende-mism	1	Asteraceae
Leucanthemum vul-gare subsp. *catalau-nicum*	Forest	r	Pre coastal, System Central Pre-Pyrenees		Rare	3	Asteraceae
Leucanthemum vul-gare vogtii	Forest		Ports		Ports Ende-mism	2	Asteraceae
Limodorum aborti-vum	Forest		General		Characteristic	3	Orchidaceae
Limodorum aborti-vum subsp. *trabu-tianum*	Dry Forests	rrr	Pre Coastal System		Rare	2	Orchidaceae
Linaria supina aeru-ginea	Rocky Pasture lands		Ports		Ports Ende-mism	2	Scrophulariaceae

Species	Main Habitat	Rarity	Location	Threat Category	Conservation interest	Priority of conservation	Family
Lonicera pyrenaica paui	Rocks		Ports		Ports Endemism	2	Caprifoliaceae
Melittis melissophyllum	Forest	r	Central Pre-Pyrenees		Rare	3	Lamiaceae
Mercurialis perennis	Forest	r	Central Pre-Pyrenees		Rare	3	Euphorbiaceae
Narcissus assoanus	Pasture lands		Ports		Protected Europe	3	Amarilidaceae
Ononis aragonensis	Open forests and rocks	rr	Ports, Pyrenees and Central Pre-Pyrenees		Rare	2	Papilionaceae
Ononis viscosa	Forest	rr	Central Pre-Pyrenees		Rare	2	Papilionaceae
Ophrys fusca	Forest	r	General		Rare	3	Orchidaceae
Ophrys passionis	Pasture lands		General		Rare	3	Orchidaceae
Ophrys scolopax	Forest		General		Rare	3	Orchidaceae
Orchis cazorlensis	Clear forests with bearberry	rrr	Ports	EN	Protected Catalonia	1	Orchidaceae
Orchis mascula	Pasture lands		General		Rare	3	Orchidaceae
Orchis morio	Pasture lands	r	Ports		Rare	3	Orchidaceae
Paeonia officinalis subsp. *microcarpa*	Forest	rr	Ports, Pyrenees and central Pre-Pyrenees		Rare, typical of the habitat and protected in Catalonia	2	Peoniaceae
Phyllitis sagittata	Shady rocks	rrr	Ports	EN	Protected Catalonia	1	Polipodiaceae
Pimpinella gracilis	Forest	rr	Ports		Rare	2	Umbelliferous
Pinguicula grandiflora subsp. *dertosensis*	Shady rocks	rr	Ports	VU	Protected Catalonia	1	Lentibulariaceae
Plathantera bifolia	Forest	r	General		Rare	3	Orchidaceae
Populus tremula	Forest	r	General		Rare	3	Salicaceae
Prunus mahaleb	Forest	r	General		Rare	3	Rosaceae
Prunus prostrata	Rocks and scrub	rr	Ports	VU	Protected Catalonia	1	Rosaceae
Pyrola chlorantha	Forest		Ports		Protected Catalonia	2	Pirolaceae
Pyrola secunda	Forest		Ports		Protected Catalonia	2	Pirolaceae
Ramonda myconi	Rocks		Ports		Protected Catalonia	2	Gesneriaceae
Ranunculus gramineus	Pasture lands	r	Ports, Montserrat, Pre Coastal System		Rare	3	Ranunculaceaes
Rhamnus saxatilis	Forest	r	Pre-Pyrenees Central and Pre Coastal System		Rare	3	Ramnaceae
Rhamus alpina	Forest	r	Pyrenees Central		Rare	3	Ramnaceae
Rosa pimpinellifolia	Forest	r	Ports		Rare	3	Rosaceae
Salix tarraconense	Shady rocks	rr	Ports	VU	Protected in Catalonia and catalan endemism	1	Salicaceae
Sanicula europaea	Forest	r	Ports		Rare	3	Umbelliferous
Saxifraga longifolia aitanica	Rocks		Ports		Protected Catalonia	2	Saxifragaceae

Species	Main Habitat	Rarity	Location	Threat Category	Conservation interest	Priority of conservation	Family
Saxifraga longifolia var. *aitanica*	Rocks	rr	Montserrat	VU (miscata-loged)	Protected Catalonia	1	Saxifragaceae
Sorbus torminalis	Forest	r	Central Pre-Pyrenees		Rare	3	Rosaceae
Viola willkommii	Forest		Ports		Protected Europe	3	Orchidaceae
Spiranthes aestivalis	Humid pasture lands	rr	Ports	VU	Protected Catalonia	1	Orchidaceae
Taxus baccata	Forest	r	General		Protected Catalonia	2	Taxaceae
Teucrium pyrenaicum subsp. *guarensis*	Forest		Pre-Pyrenees Central		Pre-Pyrenees Endemism	2	Labiadas
Thalictrum minus	Forest	r	Pyrenees Central		Rare	3	Ranunculaceaes
Thalictrum tubero-sum	Forest	r	Ports, Central Pre-Pyrenees		Rare	3	Ranunculaceaes
Thymus willkomii	Rocks	rr	Ports	VU	Protected in Catalonia and catalan ende-mism	1	Lamiaceae
Tilia plathyphyllos	Forest	r	Montserrat		Rare	3	Tiliaceae
Tulipa sylvestris subsp. *sylvestris*	Rocks	rr	Montserrat		Rare	2	Liliaceae
Valeriana apula	Rocks	r	Ports, Central Pre-Pyrenees		Rare	3	Valerianaceae
Valeriana montana	Rocks	r	Ports, Central Pre-Pyrenees		Rare	3	Valerianaceae
Valeriana montana tarraconensis	Forest		Ports		Ports Ende-mism	2	Valerianaceae
Viola willkommii	Forest		Ports		Typical of the habitat	3	Violaceae
Galatella aragonensis	Forest	rrr	General		Protected Catalonia	1	Asteraceae

r: rare; rr: very rare; rrr: exceptional; VU: vulnerable; EN: endangered.

A3. List of species of fauna considered typical of the habitat of black pine

Here it is shown a list of species of fauna created from threaten criteria, including biogeographical indicator species, typical of the habitat or species of local interest.

Group / Family	Taxon	EU Directive Annexes	Habitat affinity	Biology
Invertebrates Coleoptera	*Buprestis splendens*	II; IV	Specialist	Pinophila
Invertebrates Diptera	*Cheilosia mutabilis*		Preferential	Saproxilic larva
Invertebrates Diptera	*Merodon avidus*		Preferential	Phytophagous larva
Invertebrates Diptera	*Paragus tinialis*		Preferential	Predator larva
Invertebrates Diptera	*Platycheirus albimanus*		Preferential	Predator larva
Invertebrates Heterocera	*Dendrolimus pini*		Specialist	Pine and fir caterpillar
Invertebrates Heterocera	*Sphinx maurorum*		Specialist	Pine caterpillar
Invertebrates Heterocera	*Xanthogramma festiva*		Preferential	Predator larva
Invertebrates MacroHeterocera	*Graellsia isabellae*	II; V	Preferential	
Vertebrates Amphibia	*Calotriton asper*	IV	Non-Preferential, scarce	
Vertebrates Amphibia	*Salamandra salamandra*		Non-Preferential, scarce	
Vertebrates Amphibia	*Triturus marmoratus*	IV	Non-Preferential, scarce	
Vertebrates Amphibia	*Pleurodeles waltl*		Non-Preferential, very rare	
Vertebrates Amphibia	*Alytes obstetricans*	IV	Preferential, moderated	
Vertebrates Amphibia	*Bufo calamita*	IV	Non-Preferential, moderated	
Vertebrates Amphibia	*Bufo spinosus*		Non-Preferential, scarce	
Vertebrates Amphibia	*Pelodytes punctatus*		Non-Preferential, moderated	
Vertebrates Reptilia	*Lacerta lepida*		Non-Preferential, scarce	
Vertebrates Reptilia	*Podarcis liolepis*		Non-Preferential, moderated	
Vertebrates Reptilia	*Psammodromus algirus*		Preferential, moderated	
Vertebrates Reptilia	*Anguis fragilis*		Non-Preferential, scarce	
Vertebrates Reptilia	*Coronella girondica*	IV	Non-Preferential, scarce	
Vertebrates Reptilia	*Coronella austriaca*	IV	Non-Preferential, scarce	
Vertebrates Reptilia	*Vipera latastei*	IV	Non-Preferential, very rare	

Vertebrates Birds	*Circaetus gallicus*	I	Non-Preferential, moderated	Reproductive/migrator
Vertebrates Birds	*Accipiter nisus*	I	Non-Preferential, moderated	Sedentary
Vertebrates Birds	*Dryocopus martius*	I	Non-Preferential, scarce	Sedentary
Vertebrates Birds	*Dendrocopos major*		Preferential, moderated	Sedentary
Vertebrates Birds	*Lophophanus cristatus*		Preferential, abundant	Sedentary
Vertebrates Birds	*Periparus ater*		Preferential, abundant	Sedentary
Vertebrates Birds	*Sitta europea*		Preferential, scarce	Sedentary
Vertebrates Birds	*Serinus citrinella*		Preferential, scarce	Sedentary
Vertebrates Birds	*Loxia curvirostra*		Preferential, abundant	Sedentary
Vertebrates Mammals	*Eptesicus serotinus*		Non-Preferential	Sedentary
Vertebrates Mammals	*Plecotus auritus*	IV	Non-Preferential	Sedentary
Vertebrates Mammals	*Canis lupus*	II, IV, V	Non-Preferential	Accidental
Vertebrates Mammals	*Genetta genetta*		Non-Preferential	Sedentary
Vertebrates Mammals	*Capra pyrenaica*	II, IV, V	Non-Preferential, moderated	Sedentary
Vertebrates Mammals	*Felis silvestris*	IV	Non-Preferential, scarce	Sedentary
Vertebrates Mammals	*Meles meles*	IV	Non-Preferential, moderated	Sedentary
Vertebrates Mammals	*Myotis myotis*	IV	Non-Preferential, scarce	Reproductive/migrator
Vertebrates Mammals	*Myotis bechsteinii*	II, IV	Non-Preferential, very rare	Sedentary
Vertebrates Mammals	*Sciurus vulgaris*		Preferential, abundant	Sedentary

A4. Summary of interventions to generate deadwood

Here it is shown a summary of the silvicultural treatments done during the Life+ PINASSA project where the generation of standing and lying deadwood was included.

Relative young and dense forests:

Location	Area	Initial conditions						Post-treatment inventory		
		Initial density	Initial BA	Standing deadwood		Lying Deadwood		Initial density	Initial BA	Generated standing deadwood (DC>20) [(1)]
				Density	Dm	Density	Dm			Density
	ha	trees/ha	m^2/ha	trees/ha	cm	trunks/ha	cm	trees/ha	m^2/ha	trees/ha
Castellar de la Ribera (Solsonès)	1.73	4,601	58.5	50	7.8	896	6.0	2,612	47.4	16
Castellar de la Ribera (Solsonès)	1.43	2,039	53.5	1	30.7	13	10	1,169	40.0	12
Castellar de la Ribera (Solsonès)	1.09	2,686	52.8	-	-	50	6.4	1,393	35.4	15
Castellar de la Ribera (Solsonès)	0.38	3,680	49.0	-	-	15	7.0	1,890	33.0	10
Castellar de la Ribera (Solsonès)	0.9	3,830	62.8	99	8.9	1393	6.0	2,139	44.6	15
Castellar de la Ribera (Solsonès)	0.46	2,636	51.3	50	8.5	1393	10	1,890	42.3	11
Castellar de la Ribera (Solsonès)	1.8	2,636	61.8	50	10.2	348	7.6	1,293	38.5	8
Castellar de la Ribera (Solsonès)	0.84	2,934	55.4	50	8.5	15	6.0	1,790	42.4	6
Castellar de la Ribera (Solsonès)	1.15	2,338	58.5	50	8.8	50	8.3	1,691	46.6	5
Castellar de la Ribera (Solsonès)	1.17	3,780	63.5	-	-	13	6.0	1,691	39.9	10
Castellar de la Ribera (Solsonès)	1.53	2,188	49.2	-	-	547	7.0	1,343	37.6	8
Castellar de la Ribera (Solsonès)	1.09	3,780	69.8	-	-	10	8.0	1,592	42.1	8
Castellar de la Ribera (Solsonès)	0.59	2,338	45.6	-	-	796	8.0	1,094	32.0	7
Lladurs (Solsonès)	1.43	3,059	52.1	50	8.1	13	7.2	1,467	37.6	8
Lladurs (Solsonès)	1.99	2,313	45.6	-	-	1791	6.1	1,567	38.1	5
Lladurs (Solsonès)	2.54	2,288	37.1	-	-	19	7.0	1,443	29.7	4
Lladurs (Solsonès)	2.1	1,655	29.3	-	-	596	6.3	1,437	21.7	4
Lladurs (Solsonès)	1.71	2,014	42.8	50	5.0	348	7.3	1,020	30.9	6
Lladurs (Solsonès)	1.64	2,810	50.0	-	-	696	6.2	1,493	32.9	5
Horta de Sant Joan (Terra Alta)	18.87	2,205	51.2	25	10.0	50	7.8	1,160	36.8	6

[(1)] It refers to girdled trees during interventions.

Regularized adult forests:

Location	Area	Initial conditions					Post-treatment inventory (2 years after) (2)				
		Initial density	Initial BA	Standing deadwood	Lying deadwood	Total	Initial density	Initial BA	Standing deadwood	Lying deadwood	Total
				Density	Density	Volume (1)			Density	Density	Volume (1)
	ha	trees/ha	m^2/ha	trees/ha	trunks/ha	m3/ha	trees/ha	m^2/ha	trees/ha	trunks/ha	m^3/ha
Castellar de la Ribera (Solsonès)	2.15	1,224	39.4	0	0	0.00	665	29.0	5	16	0.59
Castellar de la Ribera (Solsonès)	1.51	1,174	33.2	0	0	0.00	580	25.1	0	8	0.18
Castellar de la Ribera (Solsonès)	2.69	1,316	37.7	0	40	12.91	503	22.2	5	57	19.35
Castellar de la Ribera (Solsonès)	1.51	1,401	43.1	0	27	3.01	679	29.1	8	63	16.43
Colldejou (Baix Camp)	1.26	1,090	41.8	0	19	3.75	622	27.6	20	19	3.75
Colldejou (Baix Camp)	16.02	1,320	34.7	1	37	3.89	688	23.6	2	45	7.82
Horta de Sant Joan (Terra Alta)	2.15	523	35.6	0	16	1.85	269	25.7	9	16	1.85
Baix Pallars (Pallars Sobirà)	14.13	566	43.2	1	43	16.12	349	29.8	1	72	26.00
Baix Pallars (Pallars Sobirà)	10.20	467	34.6	0	12	3.09	354	27.0	0	35	13.05

(1) Total volume of deadwood does not include stumps.

(2) Regarding deadwood (standing and lying), it refers to girdled and felled (left lying) trees during interventions, plus the trees that could have died naturally (for example, some stands were affected by a snow storm).

Irregularized forests:

Location	Area	Initial conditions					Post-treatment inventory (2 years after) (2)				
		Initial density	Initial BA	Standing deadwood	Lying deadwood	Total	Initial density	Initial BA	Standing deadwood	Lying deadwood	Total
				Density	Density	Volume (1)			Density	Density	Volume (1)
	ha	trees/ha	m^2/ha	trees/ha	trunks/ha	m^3/ha	trees/ha	m2/ha	trees/ha	trunks/ha	m^3/ha
Fígols i Alinyà (Alt Urgell)	24.08	1,142	34.9	0	3	0.50	862	24	8	30	5.13
Alfara de Carles (Baix Ebre)	6.76	670	26	-	-	-	427	15.8	2	2	-
Horta de Sant Joan (Terra Alta)	9.1	1,.673	50.5	0	3	0.24	980	37.2	4	11	1.04

(1) Total volume of deadwood does not include stumps.

(2) Regarding deadwood (standing and lying), it refers to girdled and felled (left lying) trees during interventions, plus the trees that could have died naturally (for example, some stands were affected by a snow storm).

A5. Technical conditions of implementation

General rules

The interventions will be adjusted to the description and quantifications specified in the operative planning. Any modification will have to be agreed between the parts and duly registered.

All machines and tools used must be in perfect operating conditions and properly revised. Operating personnel have to be properly qualified or have provable experience.

In periods of inactivity of the company during the implementation of the interventions (holidays, night, rain), the roads and the forest tracks may not be blocked by logs, machinery or other objects that may hinder or be a risk for the traffic.

If pine caterpillar plague is detected special protection measures will be taken. Likewise, if other plagues or diseases are observed that can be spread because of the works implementation, the necessary measures to avoid this spread will be taken.

Existing water points, such as water troughs and places of interest for amphibians, especially during breeding season (spring) will be maintained intact during interventions.

The interventions will be implemented outside critical breeding seasons, September to January in general. In winter interventions it is very important to maintain standing all trees with cavities or nests since they may host hibernating species such as dormouse and bats that cannot escape in the event of tree felling.

In thinnings, selective cuttings and regeneration cuttings

It is necessary to maintain a strict criteria of positive selection, respecting the best trees during the regulation of competition, and also to follow the criteria of selection of trees of interest for conservation to achieve the design of actions for conservation and improvement of biodiversity.

In the case of irregular stand management, the groups or patches of different sizes will be defined, with a recommended maximum surface of 1,000 m^2. This criterion will be adjusted for each stand, in function of the specific conditions of the trees to eliminate or to maintain.

In general, the trees must be felled with a straight cut at ground level, leaving a stump of less than 5 cm high. Nevertheless, some stumps may be left higher (40-50 cm) as part of a specific action to enhance biodiversity (see chapter 4.4).

Tree felling will be carried out avoiding damages on trees that were planned to be maintained. Moreover, the felling will be implemented so that logging is progressive with the logs aligned. The “fan effect” should be avoided, as it can damage the regeneration or other trees and vegetation if a non-aligned stem is dragged. Logging itineraries will be identified before starting the works, and will be followed.

On timber extraction

As a result of the intervention it will be possible to commercialize the timber. When felled trees are kept within the stand it will be necessary to reduce the accumulation of logging residues, by cutting the woody parts with diameter>5 cm to lengths <1 m and distributing the residues to avoid heights >50 cm.

During logging, there will be no circulation on rocky outcrops, dry stone walls, areas with species of endangered flora or on the shrubs on the stand edge.

The extraction of the complete tree will involve the shredding of branch residues to avoid accumulating large residues next to paths, unless this biomass is extracted.

Protection of natural regeneration

In those stands with a density of domestic and wild animals high enough as to hinder the development of the seedlings or of elements of floristic interest, it is recommended to control the access of the livestock or eve, protect the area under regeneration with a fence. Fencing should be done immediately after implementing the interventions and maintaining the restriction for at least 5 years.

Prevention of forest fires during the interventions

The existing legislation on forest fires prevention and control will be complied and measures may be taken to avoid unnecessary fire. The implementation of forest works during periods of fire risk can be authorised, as long as there is an administrative authorization and all the necessary means of suppression are available.

During the works, the flammable materials present in the working area will be properly protected.

Management of other wastes

All the external residuals generated (tins, packages or other objects) must be collected and removed from the forest by the operating company, and disposed selectively and according to legislation.

Packages and plastic bags and tapes, as well as other small or medium waste products that were previously in the forest will be also removed.

Figura 37. Black pine forest within Natura 2000 network, Central Catalan Pre-Pyrenees. Photo: Jordi Bas.

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