Life TAXUS

CONSERVATION OF MEDITERRANEAN YEW FORESTS

BEST PRACTICE HANDBOOK

Life

NATURA 2000

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Life
Natura 2000

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1. PRESENTATION

The yew tree (*Taxus baccata* L.) has always been a source of fascination and interest for people all over Europe. Its extraordinarily long-lasting and flexible wood has been highly valued for making all kinds of utensils since ancient times. Evidence of this is the yew wood bow, found at the archaeological site La Draga, in the Pla de l'Estany, and dated from the Mesolithic era (around 7,000 years ago). The use of yew for healing purposes also dates back to ancient times, the charred remains of yew having been found in the fires of Neolithic shepherds, where it was almost certainly used to disinfect livestock. In Celtic culture, ancient yews often presided over social or religious gathering sites, while today it is highly valued in the world of medicine for its use in chemotherapy. It is no surprise, therefore, that the yew has left its mark on our culture.

The biogeographical importance and conservation value of yew forests is a result of the regression they have suffered over the years, which has made them a rare sight across the European continent. Mediterranean yew groves, tucked away in shady ravines and often growing on stony ground, are limited to small stands. Relics from cooler times, when their distribution was more extensive, they are now in decline, exposed to genetic isolation, forest fires and extreme droughts, factors that are predicted to intensify in the context of climate change. For all these reasons, Mediterranean yews constitute a priority conservation habitat in the European Union. The iconic character of the yew makes its habitat ideal for communicating the intrinsic value of biodiversity and the benefits of the ecosystems that natural spaces provide us with.

This is the essence of the Life TAXUS project: to contribute to the active conservation of yew groves, while demonstrating the need to preserve the Mediterranean Region's natural and cultural heritage, and doing so in a way that is compatible with the activities humans undertake in the region. To achieve this, Life TAXUS has approached active conservation actions in yew groves from a global perspective, through active participation and collaboration between the world of research and knowledge transfer (the Forest Sciences Centre of Catalonia), local administrations (Consortium of the Serra de Llaberia and Alta Garrotxa and the Rasquera Town Council), protected natural spaces (the Natural Site of National Interest of Poblet) and private forest owners, with whom agreements have been set up with the support of the Land Stewardship Network. The General Management of Forests of the Catalan Government has provided technical and administrative support for all initiatives throughout the project.

In a globalised world, the factors that threaten conservation have also changed in scale, both spatially and temporally, their effects, once isolated and sporadic, becoming further-reaching and increasing in frequency. Nature conservation, therefore, cannot be limited to passively protecting iconic species and ecosystems, but rather entire regions must be managed with the active participation and consensus of all social players, meaning landowners, public administrations, scientific institutions and land stewardship organisations. Working along these lines, this manual of best practices for the conservation of Mediterranean yew groves provides the tools and experiences for actively preserving yew groves, promoting their application to relict woodland habitats across the Mediterranean and Europe.

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2. INTRODUCTION

What makes Mediterranean yew groves so exceptional is their scarcity, the environments where they can be found and, above all, the highly unique tree they contain. The yew (*Taxus baccata* L.) is a relict tree (Hampe & Jump 2011), with great ecological, cultural and therapeutic value. Few species in the world have such symbolic strength (Hartzell 1991, Cortés et al. 2000). Ever since Neolithic times, humans have been taking advantage of the wood's exceptional properties for fashioning tools, particularly bows, and have known of the extreme toxicity found throughout the tree, with the exception of its fleshy fruit (the aril). These properties, together with the tree's longevity, (there is a yew in Wales dated at 5,000 years old!) have given the yew a magical and symbolic character in the collective imagination. Its branches were used in funerals in ancient Celtic, Greek and Roman cultures and ancient trees served as centres for cult rituals and gatherings. The yew was also heavily exploited during the Middle Age for making bows. In the 20th century the yew's extraordinary organic compounds (taxanes) were found to have anticancer properties which were used to fight the illness. The already heavily reduced European species was unaffected, but the American Pacific and Asian yew populations were severely reduced as a result.

The European yew groves are now under threat (European Environment Agency, 2009) and in regression in the Iberian Peninsula (Serra Laliga 2009). A host of adverse factors have led to this situation, one being a lack of regeneration, caused by low fruit production, water stress and excessive shade. Yew regeneration also suffers from pressure from ruminant herbivores, which are tolerant to the taxine, and predators (Hulme 1996, García et al. 2000, García & Obeso 2003, Perrin et al. 2006, Farris & Filigheddu 2008, Sanz et al. 2009). An additional adverse factor is the excessive forest cover, meaning more competition from other species or, indeed, other yews (Svening & Mägerd 1999, Iszkulo & Boratynski 2004, Amalesh et al. 2007, Ruprech et al. 2010), which may eventually lead to phytosanitary problems (Caritat & Bas 2007). Another great threat to yew groves are large forest fires, which have the power to decimate entire populations, as happened in central Portugal (http://www.lifetaxus.quercus.pt), and lead to the genetic isolation of populations. In fact, the lack of genetic continuity has been described as a serious problem, as it leads to a decrease in genetic variation and increase in genetic divergence among populations (Young 1996, Dubreuil et al. 2010, González-Martínez et al. 2010). To the above, we should add that the viability of yew populations seems to be in greater danger at the southern boundary of their habitat distribution (Linares 2013); a problem that is likely to worsen as climate change gives rise to climbing temperatures and a drop in rainfall (Draper & Marques 2007, Àguila et al. 2015, Thomas 2015).

For these reasons, yew forests constitute a priority habitat for conservation in the European Union (Habitat 9580* Mediterranean forests of Taxus baccata). As a consequence, it is essential that we propose effective conservation measures both for the tree and its habitat, particularly in a context of global change and for a region as vulnerable as the Mediterranean.

This manual is an attempt to synthesise the issues and actions carried out within the Life TAXUS project (www.taxus.cat), financed by the European Union with the aim of contributing to the conservation of yew groves in the Natura 2000 spaces in Catalonia, which include practically all the known yew groves in the country. In Catalonia, 294 hectares of yew groves or mixed forests have been inventoried, where the yew has a presence with varying densities. The forest types that can be defined are widely varied, from monospecific and highly dense yew groves such as that of Miseclòs, in Alta Garrotxa, to the centennial yew grove of Cosp, in the Serra de Cardó, probably the oldest natural forest in the country. Between these are mixed forests of yew with broadleaf trees or conifers, and even small stands of holm oak, beech and pine with a high density of yews, often as an understory tree layer. In any case, they always cover small surface areas (2.5 hectares on average), distributed across the Pre-Pyrenees, from Montsec and the Ribera Salada to Alta Garrotxa; and especially across the pre-coastal mountain ranges, in the Guilleries, Cardó, Montseny, Montserrat, Prades, Montsant and Llaberia. These are relatively small areas on the southern boundary of the species' distribution, making it an especially vulnerable habitat in the regional biogeographical context and increasing the need for conservation measures to be taken.

Out of a total of 38 identified and inventoried stands, Life TAXUS has undertaken conservation actions across 195 ha. These have consisted in regulating competition to adults, juveniles and seedlings; phytosanitary treatments of yews affected by *Armillaria*; protecting regeneration from herbivores; reinforcing regeneration with the production and planting of yew seedlings; facilitating seed dispersal through silvicultural interventions; and planting fleshy-fruit producing bait plants, now companion plant life in the habitat. In addition, birdbaths have been installed to help maintain populations of seed-dispersing birds and measures taken to protect the forest against erosion and wildfire. Finally in the public sphere, the use of yew sites has been regulated, results of conservation work have been published on different media and environmental educational activities have been set up. A major event organised by Life TAXUS was the IV International Yew Workshop, held in the Poblet Monastery, in October 2014.

Life TAXUS aspires to making a decisive contribution to the conservation and diffusion of the natural value of Catalan yew groves. And in addition to this goal, through the use of yew groves as an umbrella habitat, the project, and, as a natural extension, this manual, hopes to make a modest contribution to the protection and promotion of the natural and cultural heritage of the Mediterranean Region.

3. THE YEW TREE AND THE YEW GROVES

3.1. The yew, a highly unique tree

The yew (*Taxus baccata*) is an iconic tree; it is one of the world's longest living and has tremendous cultural, natural and scientific heritage value. The yew is a unique tree in many different ways; it is a dioecious conifer that is poisonous, and not resinous, from the Taxaceae family. The elasticity, strength and reddish colour of its wood, its slow growth and extraordinary longevity are its defining characteristics (Abella 1996). The Greeks gave the yew the name *Taxus*, a term that could refer to two of the tree's important elements: taxon, meaning bow, or *toxikon*, which is ancient Greek for poison (Iglesias et al. 1997).

Taxonomy

Bolòs & Vigo (1989) ascribe to Taxus baccata the following taxonomic scheme:

- Division ➝ *Pinophyta*
- Subdivision ➝ Spermatophytes (Phanerogamae)
- Class ➝ Gymnosperms
- Subclass ➝ Conifers
- Order ➝ Taxales
- Family ➝ Taxaceae
- Genus ➝ *Taxus* L.

1. State of conservation

The IUCN classifies the yew as Least Concern, LC, on an international scale. Its habitat has priority conservation status in Europe (see chapter 3.5).

In Catalonia, *Taxus baccata* is protected by the order of 5/11/1984 published in DOGC on 12/12/1984 (Cortés et al. 2000). It is not classified as a threatened species in the Catalogue of Threatened Flora of Catalonia (Decree 172/2008 resolution).

2. Description

The yew (*Taxus baccata*) is a non-resinous evergreen tree, with a corpulent shape, which can reach a height of 20 m, although it more commonly reaches a maximum height of 8 to 15 m. The trunk can measure over a metre in diameter at chest height. In unfavourable conditions it is reduced to having a bushy appearance. Its root system is highly developed and reaches deep into the ground, the trunk is short and thick, sometimes formed by the union of several stems, the perimeter of exceptional specimens measuring more than 6 metres. The brown bark, peels off in fine, elongated flakes, revealing reddish plaques beneath. The crown, under normal conditions, has a very distinct dark silhouette which is rounded and very open, with protruding branch tips (Cortés et al. 2000). The branches are long, thick, alternate and flexible, and slightly recurrent at their ends to the extent that they can touch the ground.

Figure 1. Monumental yew of Torrent de l'Orri (Alta Garrotxa). Photo: Jordi Bas

The crown is dense, wide, oblong or conical and dark green in colour. The branches are abundant, long, horizontal and flexible and the highly numerous twigs give the treetop a dense appearance. The adventitious shoots are greatly abundant on the trunk and in the crown and produce, beneath the bark, a large number of dormant buds that are stimulated by pruning, wounds or mutilations (Sobrón 1984).

The leaves are persistent, living for around eight years; they insert spirally and are arranged in two flat rows; they are needle-like and flat, narrow, lanceolate and sharp; they measure between 10 and 30 mm long and 1.5 mm wide, arranged in a pinnate (feather-like) form along the length of the branch. They are a dark green colour on the front side and lighter green on the back of the needle (Cortés et al. 2000). The old leaves fall in the spring when new ones come through. The yew is a dioecious species, which means that some individuals only have male organs (male trees) and others have only female organs (female trees). Both the male and female organs are small and not very visible (Fernández et al. 2004). Very occasionally a monoecious specimen can be found, which explains how solitary individuals can bear fruit (Vives 2006).

Figure 2. Detail of yew bark and leaves. Photo: Jordi Bas

3. Flowering

Regular flowering takes place late winter or early spring. Female trees bear fruit every year, as long as they are not too far away from male trees (Ruiz de la Torre & Ceballos 1979). Both female and male trees bear fruit from 20-30 years of age (Cortés et al. 2000).

The male cones appear on the axils of leaves from previous years, at the lower part of the branches (figura 3). They are globular and yellow. They are solitary strobili, with 6 to 12 fleshy scales, each of which has 3-9 pollen sacs. The pollen is dispersed by the wind. The female cones can be found alone at the end of a small axillary axis covered in bracts, giving them the appearance of scaly buds (Fernández et al. 2004). They contain a single seed and are wrapped in various sterile bracts. Once fertilised, the female cones turn into eye-catching fruits when they mature in late summer or autumn (figure 4).

The fruits (in fact false fruits with a single seed inside) are red, measuring 8 to 12 mm in diameter, and have a fleshy outer layer which covers three-quarters of the seed. This wrapping, called an aril, turns red when ripe (Cortés et al. 2000).

Taxus baccata is a highly toxic species, thanks to the potent *taxine* alkaloid. The red, fleshy and sweet aril is the only edible part of the tree. (Folch et al. 1988). The ovoid, dry, brown seeds are covered by a woody episperm, which is not very hard and ends in a small tip (Cortés et al. 2000). The young embryo can stop growing and remain dormant for months or even years (Folch et al. 1988).

Figure 3. Male yew flowers forming, with the stamen still inside the scales. Photo: Jordi Bas

4. Vegetative growth

Its growth in length is very slow, 1 cm in the first year and 2 or 3 in the second, then growing till the sixth year at a rate of 3 cm per year. After, its development continues at a slow pace, with exceptional rates of 15 to 20 cm annually (Sobrón 1985). Because of its resistance to plagues, drought and even fire, it is one of the longest-living known species (García et al. 2001). It has a superficial root system formed by long horizontal roots. It also grows in girth at a slow rate, with trunks measuring 20 to 40 cm in diameter estimated at 80 to 100 years old (Cortés et al. 2000). It is quick to produce shoots along its branches and reacts well to pruning (Galán et al. 1998). It is very difficult to know with accuracy how old individual trees are; some specimens in England have been estimated at over 2,700 years old. It is one of the longest-living species in Europe (Ruiz de la Torre & Ceballos 1979).

5. Bearing fruit

From 20-50 years old, the tree regularly produces fruit each year, although in certain, less than optimum, sites in Eastern Europe, especially abundant fructification has been observed every 2-3 years. The fruits normally appear in the autumn (from August to November) of the same year and remain on the tree for a period of time (Abella 1996).

The seed has an oval-oblong shape, with an elliptical cross-section, encased in a kind of hood known as the aril, which is open at one end, fleshy, succulent, a little viscous and sweet inside. It is first green and then red when mature. The seed and aril as a whole (aril) has the appearance of a globular drupe which is slightly compressed along its length (Ruiz de la Torre & Ceballos 1979).

Table 1. Biological phenogram of the yew. Source: Cortés et al. 2000.

	J	F	Mr	A	My	Jn	Jl	A	S	O	N	D
Vegetative activity		From end-February to mid-November										
Dormancy		From mid-November to mid-February										
Flowering		From February to April										
Fructification					From May to August							
Fruit ripening								From August to November				


Figure 4. Yew in full fruit. Here we see the branches laden with arils. Photo: Jordi Bas.

6. Dispersal

The tree's zoochorous dispersal is carried out mainly by birds, but also carnivores (see chapter 3.3 for more details of the dispersal process). The bright red or orangey aril when mature stands out on the dark green background of the leaves, which makes it particularly attractive for the animals that feed on it. Many vertebrates ingest the whole arilocarp, but are only able to digest the fleshy aril and expel the seed along with their excrement. This not only favours the dispersal of the species, but also prepares the seeds for germination, as the gastric juices in the stomach inhibits their inherent dormancy. This could be the reason why yews are often found in stony places, as these are where animals will often deposit their excrement. (Galán et al. 1998). Although it has been shown that passing through the digestive tract does not improve rates for germination and transformation into a yew seedling, the seeds without the aril show subsequent growth percentages that are higher than for seeds with the aril. (Caritat & Bas 2007).

Rodents are the main predators of yew seeds as they break the hard covering and make the seeds unviable when they digest their nutritive tissues (Hulme & Borelli 1999, Crespo et al. in Cortés et al. 2000, Thomas & Polwart 2003). Nonetheless, they can disperse a considerable number of seeds (Thomas & Polwart 2003), making the rodents' predation-dispersal role, on occasion at least, advantageous for the yew.

Figure 5. Robin with aril. The thrush family are the main dispersers of the yew. Photo: Jordi Bas

7. Germination

Some authors say that the yew presents epigeal germination (the seeds do not need to be buried to germinate) and others, less often, hypogeal germination. However, Cortés et al. (2000) sustains that both are correct as good germination results have been obtained from both types. Many authors agree on the difficulty this species has in germination (Ríos et al. 2015). Just a small portion of seeds will germinate in the first year, the rest will do so in the second or third. According to Thomas et al. (2003), although the seed viability is close to 100%, the normal germination rate stands at around 50-70%.

The seeds of Taxus baccata have a dormancy that lasts around two years in the ground, which constitutes a disadvantage for their survival (Hulme & Borelli 1996). Some techniques to favour germination subject the seed to scarification or soaking processes that break the covering. Stratification systems are also used, in which the seeds are kept in boxes of wet sand at around 20ºC for two or three months, and then for a time at 4 or 5 ºC (Abella 1996). A kilo of arils contains more or less 8,000 seeds and in a kilo of seeds, once free of their protective covering, there can be more than 13,000 units (Carrasco 1989). The methods are clearly outlined in García-Martí 2007, Ríos et al. 2015. Although, the best system for reproduction is through the seed, it can also reproduce asexually through stolons, seem cutting or grafting.

Figure 6. One-year-old yew seedlings. Alta Garrotxa. Photo: Jordi Bas.

8. Herbivory

The entire plant, except for the pulp and aril, is toxic because of the taxine alkaloid. Cornevin (1892, cited by Clarke et al. 1981) provides the lethal oral doses for different species (in grams of leaves per kg of animal weight): donkey and mule 1.6 g; horse, 2 g; pig, 3 g; dog 8 g. sheep and cattle, 10 g, goat 12 g; rabbit 20 g. The strong resistance that ungulates have to its toxicity may be because the taxine is diluted with the content of the rumen (Clarke et al. 1981). Herds of domestic goats and cows can cause great damage to yew regeneration. Rabbits, although they also gnaw on the yew, are not normally so damaging. Red squirrels gnaw at the bark, the branches of the seedlings and also eat the arils.

Figure 7. Ruminants have a high tolerance to taxine and often browse seedlings and young yews, which can seriously harm regeneration. Photo: Jordi Bas.

3.2. Yew groves: description and composition

In the Mediterranean and Middle-European mountains the yew is mostly found on north-facing slopes, under the canopies of deciduous or mixed pine forests. In increasingly restrictive climate conditions, the yew finds refuge in small, damp sites that are protected from excessive heat (Thomas & Polwart 2003). In the Iberian Peninsula they live at a wide range of altitudes, from 100 metres above sea level in Cantabria to 2,100 m in Sierra Nevada, but in the eastern half of the Peninsula they are found at elevations of between 500-600 and 1,700 m (Cortés et al. 2000).

In Catalonia, yew groves constitute a rather scant and localised plant, covering small surface areas but with a very wide distribution. They can be found throughout the Pre-Pyrenees and coastal mountain ranges, from Albera to Els Ports in Tortosa. In general, the yew populations in Catalonia are in mountainous areas, in high and inaccessible places such as limestone cliffs, gullies and shady sites; or they are spread out across different communities of beech, oak, pine or holm oak. This situation can also be seen in other parts of the Mediterranean Basin, like in Turkey (Kaya & Raynal 2001) or North Africa (Corts et al., 2000). Often yew groves are purer and/or the yew appears in the same proportions as the other species of deciduous trees; a situation replicated in other places in the Mediterranean, such as Corsica (Laguna & Gamisans 2007) or Sicilia (Bacchetta & Farris 2007).

The yew is often accompanied by mesophilic shrub and herbaceous species. When the yew grove is dense, the flora of the understory is of low density, consisting of shade-tolerant and herbaceous species and few shrubs. In less dense areas they mix with the species from the dominant forest community, whether pine, holm oak (Costa et al. 1998), beech or oak.

The yew can be considered as a species that is at home in a wide range of environments. It can live in soils with very different characteristics, whether poor or rich in nutrients, and with all kinds of exposure levels, in shady spots or with high levels of light. However, as a preference it will always choose places that are cool, damp and shady. The main limiting factor is water availability, whether from the soil or the atmosphere (Cortés et al. 2000).

Figure 1. The Cosp yew grove, (at the top on the right) immersed in the Mediterranean landscape of the Serra de Cardó. Photo: Jordi Bas.

Figure 2. Diagram of a yew grove on a limestone cliff in the Catalan Pre-Coastal Range. Drawing: Pere Rovira from the original by Josep Nuet i Badía.

1. Factors that restrict the establishment of Mediterranean yew groves

Climate factors

This is a species best suited to a temperate Atlantic ecology, with a central European climate (Cortés et al. 2000), but one which penetrates areas with a Mediterranean climate, with annual rainfalls of around 600 mm and relative humidity of, on average, over 70%. Its optimum rainfall stands at around 850-900 mm annually. It tolerates relatively wide ranges of heat, although it avoids continentality. While in the summer the limiting factor is drought, in winter it is the low temperatures that set the altitude limit of the species (it suffers during prolonged frosts) and which determine its location in more protected ravines (Serra, 2009). It has been observed that fog is an important climate factor for yew that live outside of Atlantic areas (Cortés et al. 2000, Serra 2009).

Its location inside of the circum-Mediterranean environment is connected with the existence of mountain ridges where heat and water conditions are most in line with those of its optimum area of central and western Europe. To occupy the largest possible number of spaces, the yew is spread out in a widely diverse range of environments. Its climatic versatility, once its minimum water needs for survival are met, gives it an adaptability that counters its slow growth. At times it can even be moved from its optimum climate by competition from broadleaf trees, a species with a much faster growth rate (Sobrón 1985).

In the Iberian Peninsula the yew is distributed in areas with an Atlantic climate, sub-Mediterranean environments and also Mediterranean areas, where it generally finds refuge in cool, shady sites.

Topographic factors

Topography has a strong influence in the differentiation of local microclimates. On the limits of the yew's distribution, as is the case in the southern Mediterranean, the role of the topography is key (Sobrón 1985).

Its slow growth, frugality and mechanical resistance, allow it to live in rocky areas and cliffs, generally with shady conditions and where water availability is high and sunlight exposure low. It is often exposed to steep slopes and falling rocks. It is not the optimum situation for the yew, but rather the consequence of competition with broadleaf trees and the effect of natural or anthropic disturbances.

The shady orientation of yew sites is almost a constant in the distribution of Taxus baccata in areas with a Mediterranean climate. This is largely because this is where the coolest and dampest environmental conditions can be found and because the yew is shade-tolerant. In areas with a more Atlantic climate the yew is indifferent to which direction the slope faces, often preferring somewhere with greater sunlight exposure. In the mountains in the centre and centre north of the Iberian Peninsula easterly orientations predominate, where there is less likelihood of frost. In the southern half, they are located, almost without exception, on north-facing slopes or in shady hollows.

The slope determines a series of mechanical processes that have as much of a direct influence on the tree as they do an indirect one through the soil, and favour the establishment of the yew before other more demanding plant species. The yew can root on steep slopes often with a gradient above 25-30º. It adopts subvertical positions on rocky escarpments.

Lithology and edaphology
Although much of the literature indicates the yew's preference for calcareous substrates, this species can live in a wide variety of different soil types. Nonetheless, in the Mediterranean region it is more abundant in limestone than siliceous areas, as yews do not like the soil to be too acidic. Although it often establishes itself almost exclusively on initially eroded soil or lithosol, its absence from well-developed soils seems to be more a consequence of competition from other woody species, which would struggle to live in skeletal soils, where the yew can grow.

The yew's slow growth means it is often surpassed by other more competitive species when it comes to colonising the best soil (Sobrón 1985), and therefore forms mixed communities or is relegated to the understory or to forming groups of regenerated yews in woodland clearings.

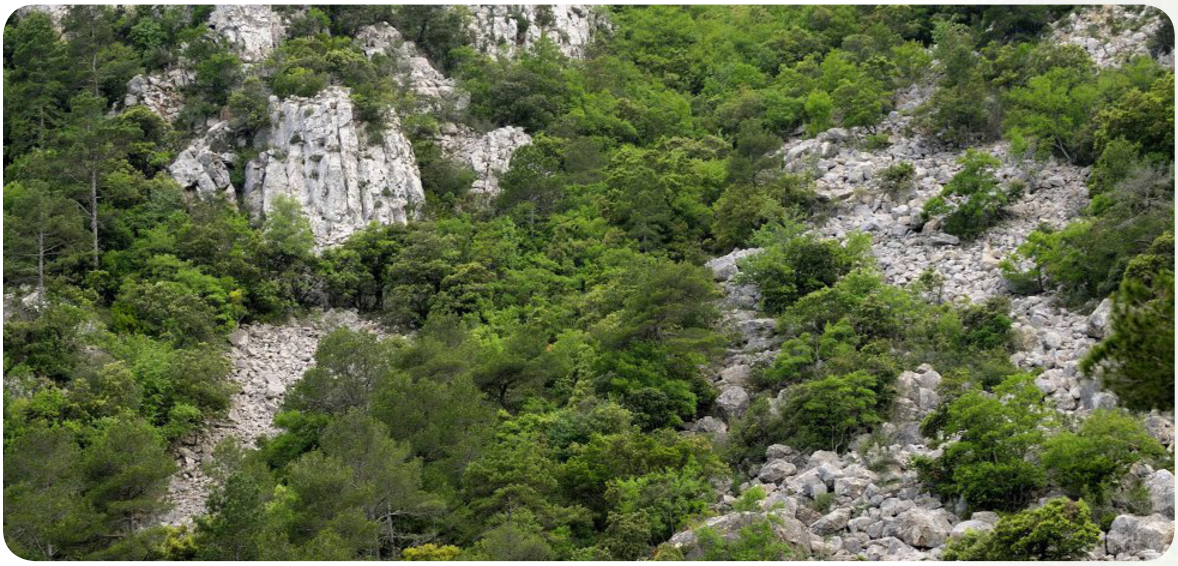


Figure 3. A gully with low yews located between rocky outcrops and scree slopes in the Serra de Llaberia. Photo: Jordi Bas.

2. Structural typology of yew groves

In terms of the structure of woody species, Caritat *et al*. 2015 classify the Catalan yew groves into 6 woodland typologies. Although they can form dense, monospecific or mixed forests, they are often a companion species, with greater or lesser abundance, scattered throughout the forest and in some cases forming regeneration groups around seed trees.

- **Type 1. Dense yew grove.** Fairly young and quite dense forest, dominated by yews and mainly accompanied by species of *Quercus* that are quite regular in structure and dominated by small and medium-diameter classes.
- **Type 2. Mixed yew forest with conifers and broadleaf trees.** Closed forest with semi-regular structure, with a not excessively dense dominant layer of adult pines (*Pinus sylvestris, P. nigra* and/or P. halepensis), and a second dense layer comprising mainly holm oaks and yew. Other broadleaf species (*Acer* sp. pl., *Ilex aquifolium*, etc.) are also commonly found as companion species.
- **Type 3. Mature yew grove.** Not very dense forest with semi-regular structure, with a dominant layer comprising very mature yew individuals, and a second layer of young trees of varying species (mainly the *Quercus Pinus* genus and yews).
- **Type 4. Holm oak forest with yew.** Very dense and regular forest containing species of *Quercus*, mainly holm oak, with other hardwoods and the presence of the occasional pine and yew.
- **Type 5. Beech forest with yew.** Semi-regular structure and notable density of beeches with young companion yews and beech regeneration.
- **Type 6. Pine forest with yew.** Not very dense, mature forest dominated by pines (*Pinus sylvestris* o *Pinus nigra*), with a younger layer of *Quercus* species, with yews and other evergreens. Similar to type 2, but with a higher and denser tree layer.

The total density of the different tree species in well-formed yew groves range from 2,000 trees/ha (Poblet) to 3,000 trees/ha (Alta Garrotxa). The yew tends to increase its density in the more northerly areas, with values that range from 254 trees/ha (Poblet) to 528 trees/ha (Alta Garrotxa) (Àguila et al. 2015). They are very low densities if compared with the studies conducted by Thomas & Polwart (2003) in which, in optimum conditions, yew densities in Denmark were recorded at 1,388 trees/ha. On the other hand, these densities are considerable when compared with yew groves in Navarra, which range from 11 to 240 trees/ha (Schwendtner et al. 2007). Average heights in Catalonia fluctuate between 3.6 m and 7.9 m. (Caritat & Bas 2007, Àguila et al. 2014). Figures 4 to 14 show the basic dasometric data for the main action areas of the Life TAXUS project.

Figure 4. Dense yew grove (type 1) on deep soil in Miseclòs (Alta Garrotxa), with a stand yew height of 15 m and average adult yew diameter of 10.4 cm (2.5-30.8 cm). The canopy density (an average canopy cover of 81%), which is mainly yew (66%), hinders the regeneration of other tree species. The understory is very poor (10% shrub and 2% herbaceous cover) due to the high tree cover and cattle grazing. Photo: Jordi Bas.

Figure 5. Mixed yew grove (type 2) in a hollow in Barranc del Titllar (Bosc de Poblet), with a stand yew height of 9.8 m and average diameter of 17 cm (4-29 cm). The canopy density gives an average canopy cover of 80%, with 53% cover of yew in the densest areas. The understory is not very dense in the areas with the strongest canopy cover, with 25% shrub and 10% herbaceous cover (Vives 2006). Photo: Jordi Bas.

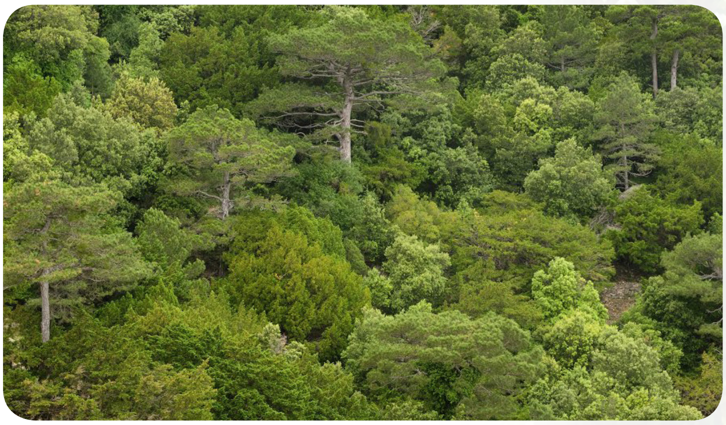


Figure 6. Mature yew grove (type 3) on rocky soil in Cosp (Serra de Cardó), with a stand yew height of 8.1 m and average adult yew diameter of 41 cm (17-65.5 cm), with large companion black pines (*Pinus nigra*). The canopy density gives an average cover of 55%, consisting largely of yew (47%). The understory is scant (21% shrub and 6% herbaceous cover) due to goat grazing. Fotos: Jordi Bas.

Figure 7. Mixed yew and holm oak forest (type 4) on rocky soil in the Serra de Llaberia, with a stand yew height of 15 m and average diameter of 9.8 cm. The canopy density gives an average cover of 81%, consisting largely of yew (66%). The understory is mostly poor (10% shrub and 2% herbaceous cover) due to the high tree density, but is dense and dominated by rough bindweed (*Smilax aspera*) and/or *Viburnum tinus* in clearings and the most open stands (Camprodon et al. 2010). Photo: Jordi Bas.

Figure 8. Beech forest with small yew stands (type 5) in the Pla de la Calma (Montseny). The stand yew height is 4.6 m with an average diameter of 10.4 cm. The canopy density gives a cover of between 40 and 80% depending on the yew density. The understory is mostly poor (10% shrub and 5% herbaceous and moss cover) due to the high tree density. Photo: Antònia Caritat.

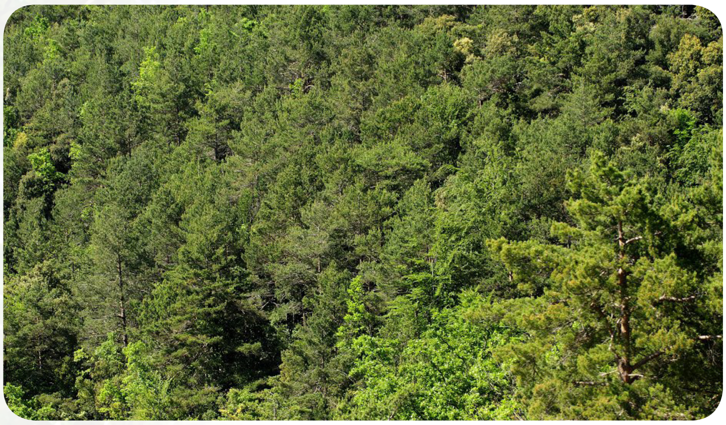


Figure 9. Pine forest with yew (type 6) in l'Alta Garrotxa. The stand yew height is 5.7 m with an average diameter of 4.1 cm. The canopy density gives an average cover of 80%, between 20 and 40% of which is occupied by the yew as a co-dominant companion species, which also forms an understory tree layer. The understory is mostly poor (5% shrub and 5% herbaceous and moss cover), due to the high tree density. Photo: Jordi Bas.

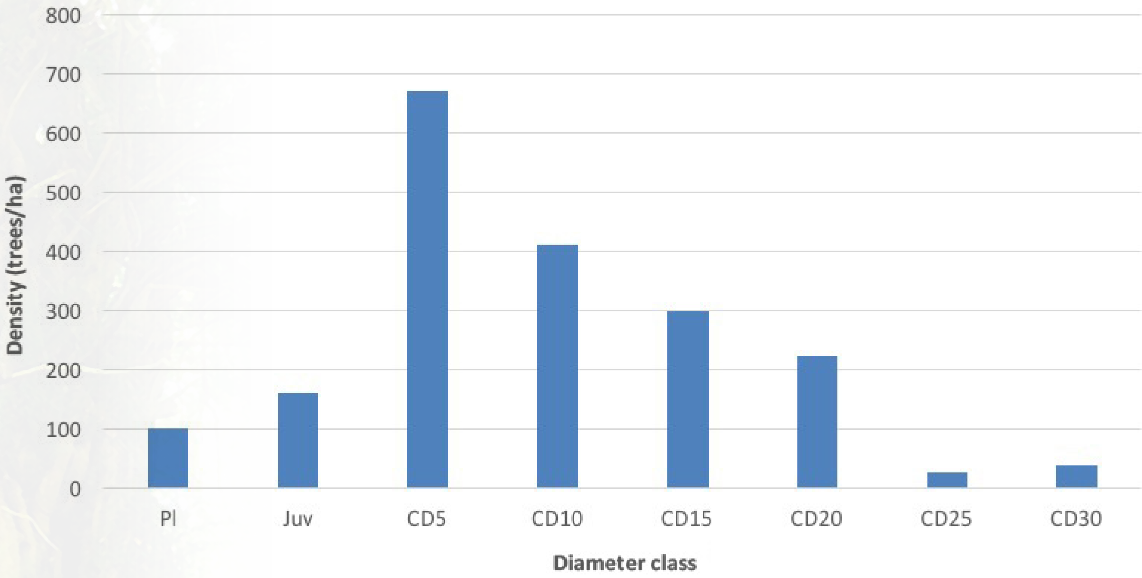


Figure 10. Distribution by diameter class of the yew in the Miseclòs yew grove (Montagut, Alta Garrotxa). Pl: seedlings (h<1.3 m), juv: juveniles (h>1.3m and DBH<2.5 cm). Photo: Jordi Bas.

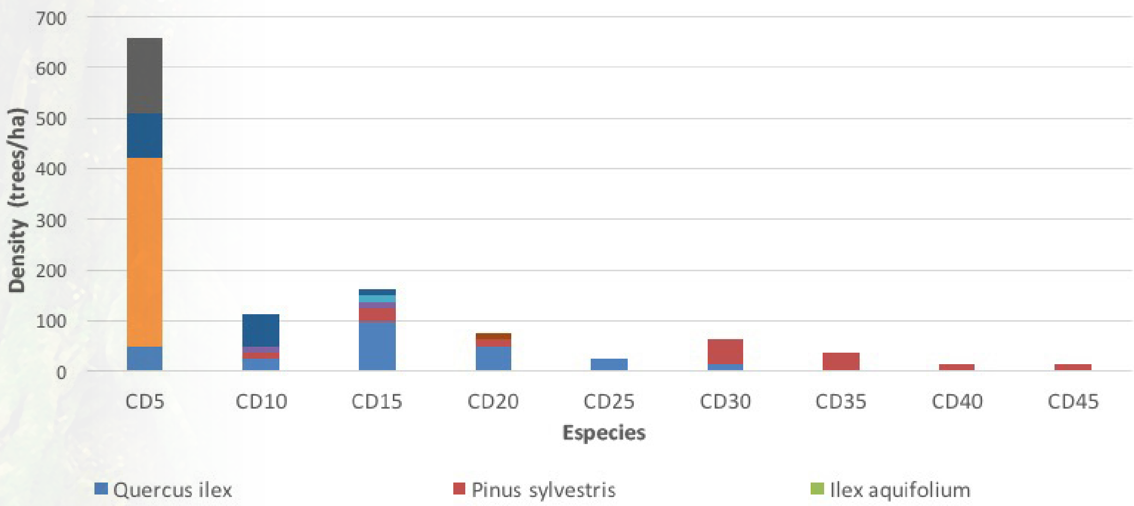


Figure 11. Distribution by diameter class of companion species in the Miseclòs yew grove (Montagut, Alta Garrotxa).

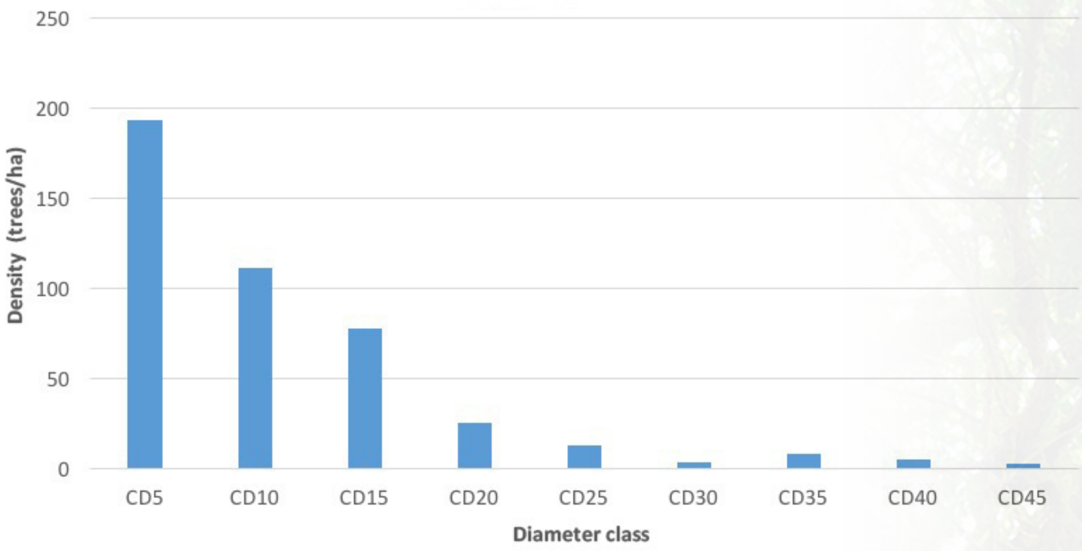


Figure 12. Distribution by diameter class of yews in the Barranc del Titllar yew grove (Vimbodí i Poblet, Bosc de Poblet). Regenerated yew up to 2.5 cm with DBH have not been represented for reasons of scale; they represent an average of 1,078 trees/ha.

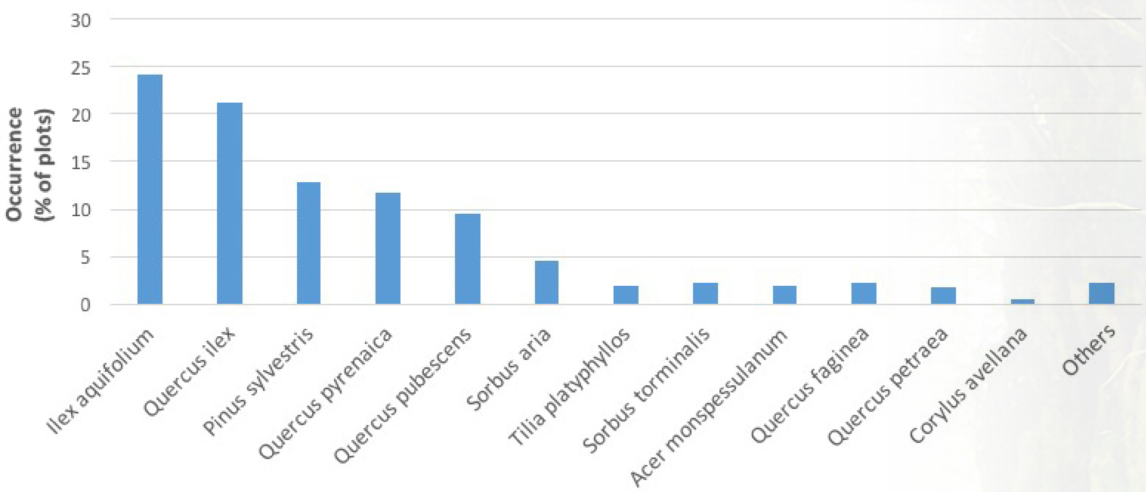


Figure 13. Percentage of distribution by diameter class of companion species in the Barranc del Titllar yew grove (Vimbodí i Poblet, Bosc de Poblet).

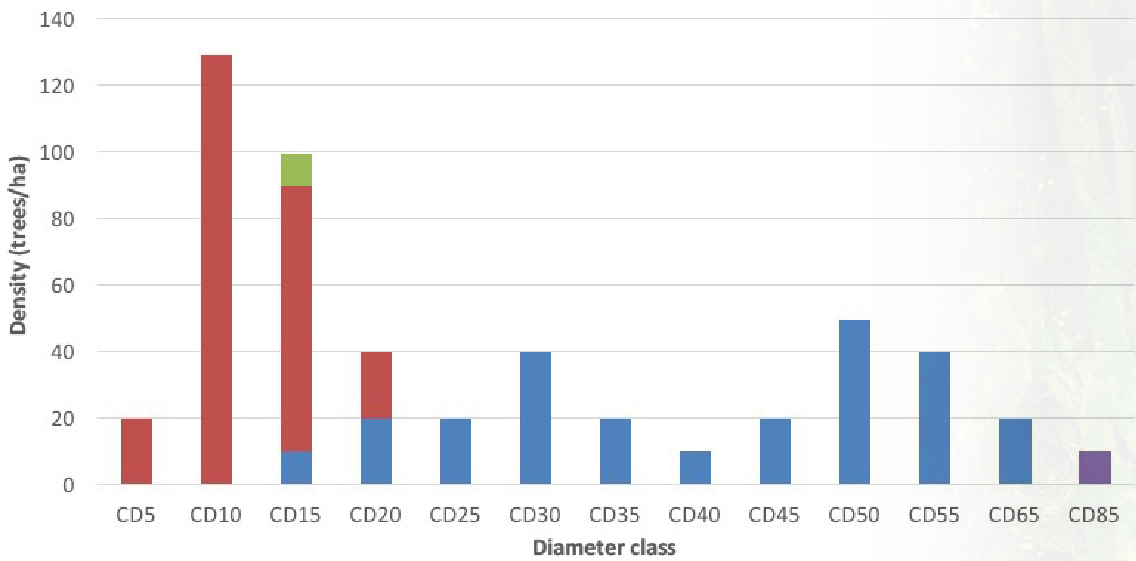


Figure 14. Distribution by diameter class of the Cosp yew grove (Rasquera, Serra de Cardó). No presence of regenerating or juvenile yews in the sites under study.

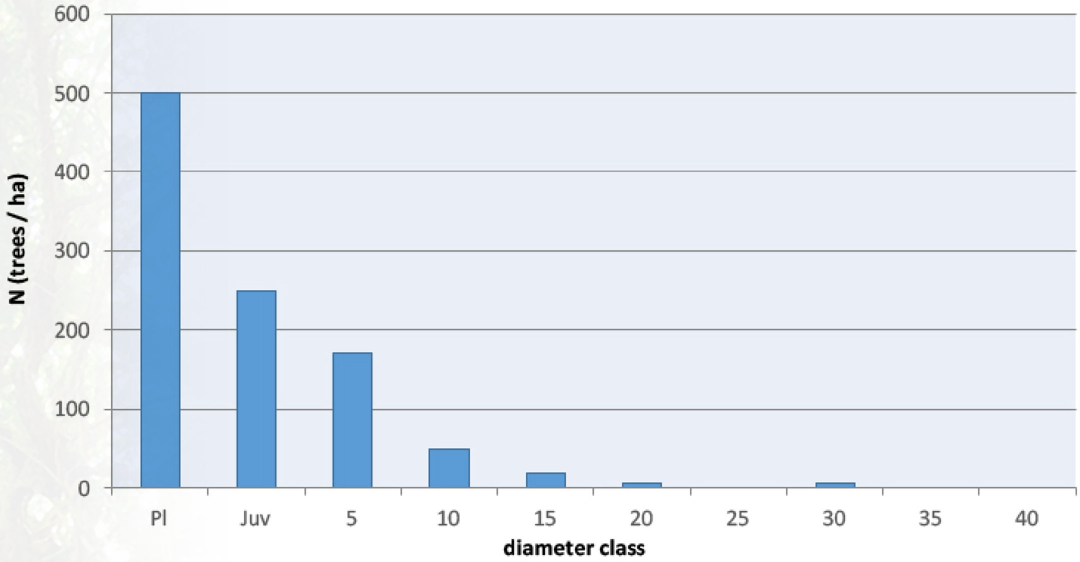


Figure 15. Distribution by diameter class of yew in the Serra de Llaberia yew groves (Capçanes-Colldejou). Pl: seedlings (h<1,3 m), juv: juveniles (h>1.3m and DBH<2.5 cm).

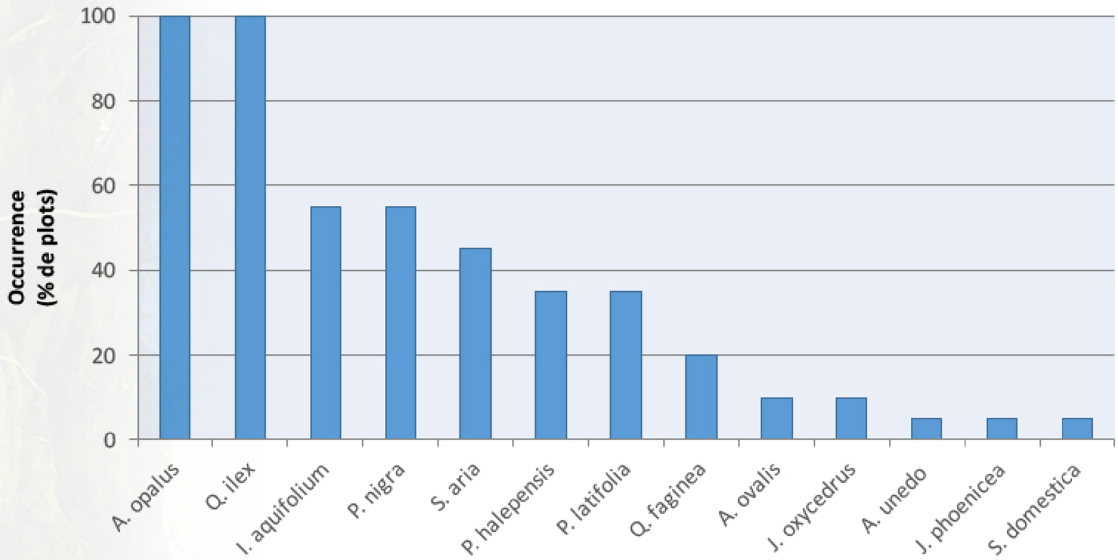


Figure 16. Percentage of distribution by diameter class of companion species in the Serra de Llaberia yew groves (Capçanes-Colldejou).

3. Flora typology in yew groves

The ecological range of the yew means that it can be found in plant communities with diverse biogeographical distribution: Euro - Siberian with an Atlantic climate (beech forests and mixed deciduous forests), sub-Mediterranean (oak forests and pine forests of either Scots or black pines), and Mediterranean (mountain holm oak forests). They are mostly found in forests but they also appear in shrub communities. In an initial analysis of the phytosociological behaviour of the yew throughout the Iberian Peninsula, carried out by Lence et al. (2010), the yew was found in more than 70 plant associations assigned to the different aforementioned syntaxonomical classes, which shows the diversity of the environments where the yew can live.

On the Iberian Peninsula two large typologies of communities where yews grow can be distinguished: 1) those found in the north and west Atlantic, where the yew is mostly associated with deciduous forests and more humid and damp environments, such as beech or birch forests, and even riparian woodland (Romero 1993, Sanz et al. 2007, Schwendtner et al. 2007, Lence et al. 2011, Rodriguez et al. 2011, Portela-Pereira 2016); and 2) those found in the Mediterranean region to the east, which stretches from Aragon and Catalonia towards the mountains in the south of the Peninsula, where the yew is associated mainly with Mediterranean and sub-Mediterranean communities (oak, pine and holm oak forests) (Nuet and Parareda 1982, Alcober et al. 1988, Costa 2007, Andrés et al. 2007, Medrano 2007).

The only yew grove community described in the Iberian Peninsula is the association *Saniculo europaeae-Taxetum baccata*e, described initially in Catalonia (Bolòs 1967) and which is also found in Aragon (= *Taxo baccatae-Tilietum platyphylli,* Pitarch 2002). It is a mesophilic forest community rich in Euro Siberian species. The dense tree layer is constituted by *Taxus baccata* and certain deciduous trees such as *Sorbus aria, Acer opalus, Populus nigra, Tilia platyphyllos, Ulmus glabra* or *Fraxinus excelsior*. The shrub layer is dominated by *Corylus avellana, Ilex aquifolium, Hedera helix* or *Daphne laureola*. The herbaceous layer is characterised by the presence of mesophilic plants like *Sanicula europaea, Poa nemoralis, Campanula trachelium, Brachypodium sylvaticum, Aquilegia vulgaris, Lilium martagon*, etc. In the most rugged enclaves, the community becomes poorer in species and certain rupicolous species may appear (Bolòs 1967).

A Principal Components Analysis of the inventories published in the Biodiversity Data Bank of Catalonia where the yew is shown to have more than 5% cover and other unpublished studies carried out on Catalan yew groves as part of the Life TAXUS project (Capdevila & Casas 2014), shows that yews can be clearly separated into different floral types, which can be synthesised into three large biogeographical groups:

1. Beech forests with yew and nuclei of yew associated to beech forests.
Nemoral species from humid environments with an Atlantic distribution, typical of the *Fagetalia* order and *Fagion* alliance. They are found in mountainous areas with a humid, Atlantic climate, such as Montseny and Ports.

2. Sub-Mediterranean oak forests, Scots pine forests and mountain holm oak forests with yew and yew groves of *Saniculo-Taxetum*
SThese are typical montane forests with a sub-Mediterranean climate, with species typically found in deciduous forests from the *Quercetalia pubescentis* alliance and *Quercion pubescentis-petraeae* order. This group includes many of the yew groves found in central and northern

Catalonia and in the Pre-Pyrenees (Montserrat, Serra d'Odèn, Alta Garrotxa and Osona) and also in some mountains in southern Catalonia (els Ports and Prades).

3. Lowland holm oak forests and Mediterranean Scots or Aleppo pine forests with yew
The yew groves found in the coastal ranges in southern Catalonia, like the Serra de Llaberia and Serra de Cardó are linked with lowland holm oak forests. The yew's companion species are Mediterranean plants typically found in holm oak forests (of the *Quercetea ilicis* class and *Quercetalia ilicis* order). Generally speaking, these yew groves are located on shady slopes and at the feet of cliffs in coastal mountain ranges, where a higher level of humidity is maintained, enabling the presence of certain sub-Mediterranean, mesophilic species, typical of deciduous forests (from the *Querco-Fagetea* class).

From this analysis it can be concluded that the yew groves present in Catalonia are associated with three large forest types: beech, oak and holm oak, which are distributed in an altitudinal gradient and biogeographical distribution (Atlantic - sub-Mediterranean - Mediterranean) related with a certain humidity and edaphic gradient.

Figura 17. The understory at a dense yew grove in Miseclòs (Alta Garrotxa). Photo: Jordi Bas.

3.3. Habitat dynamics

Until the early 20th century many European woodland areas were kept open for crops or grazing or had a low density to facilitate their use for wood. The move towards more closed woodland conditions arose as these practices were gradually abandoned (Peterken 1996). The return of the forest has, in part, enabled the Mediterranean yew groves to recover somewhat, in a scenario of generalised regression (see chapter 4.6). However, although the yew is a shade-tolerant tree (Thomas & Polwart 2003), the closure of tree canopies and increase in the competition is leading to scant recruitment and rising mortality among adults (Iszkuło 2010, Ruprecht et al. 2010, Dhar et al. 2007). The moderate opening of the tree canopy, however, favours the expansion of the yew (Svenning & Magärd 1999, Camprodon et al. 2015). The Catalan yew groves are, in general, relatively young (with the odd exception), with a clear dominance of seedlings, juveniles and adults of low diameter classes and very few trees with a diameter class of 20 or above (see chapter 3.2). The regeneration processes and evolution of the Catalan yew groves towards more mature communities depends on various interacting factors (figure 1). This chapter looks at the dispersal process and how it influences the regeneration of yew groves.

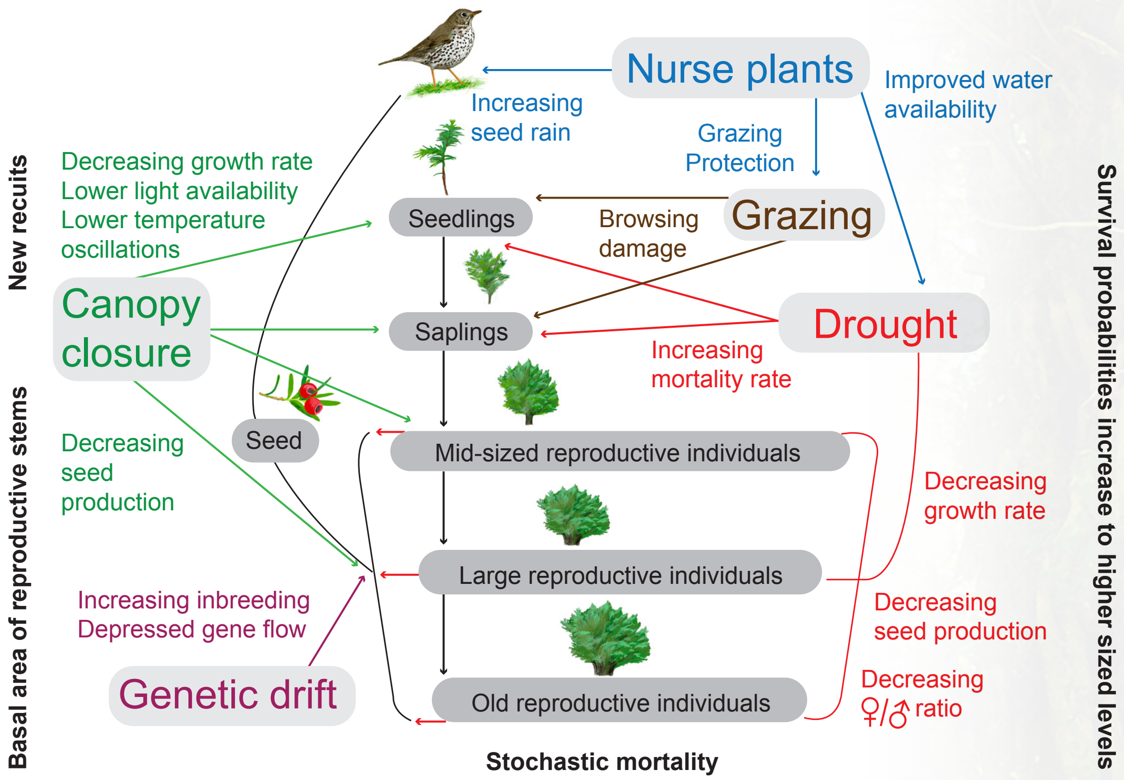


Figure 1. Stages of yew growth in relation to the environmental variables that influence its recruitment and maturity: nurse plants, herbivory, drought, canopy closure (competition) and genetic drift. The thickness of the arrows represents the theoretical magnitude of the effect of the variables. Drawing: Anna Gallés. Original by Linares 2013.

Although the yew can reproduce vegetatively through adventitious roots, especially when it is old, the regeneration of yew groves depends on sexual reproduction and, largely, on the close mutualistic relationship between plants and seed-dispersing animals (zoochory). In this mutualism, animals obtain a generally abundant food supply with a high caloric content and the plant is able to disperse its seeds by developing brightly coloured fleshy structures packed with sugars (the aril for the yew).

Yew individuals tend to group in formations of varying densities known as yew groves. Other woody zoochorous plants participate in the formation of yew groves which share certain seed-dispersing animals with the yew, forming a complex network of ecological interactions (Martínez et al. 2008, Lavabre 2008, García et al. 2013, Peredo et al. 2013). The heterogeneous structure of this network, as is the case in other regions (Cantabrian mountains), may suggest a strong functional complementarity. The interactions are mainly organised into two subgroups of species: one formed by trees, dispersed predominantly by birds, such as the holly, and another composed of shrubs, dispersed mostly by mammals. In this network there are also species like the yew, which can be dispersed by both birds and mammals.

In the Cantabrian mountains it has been seen that despite the large amount of seeds that birds take from the trees, most of the yew seeds fall from the tree by themselves landing beneath the canopies of adult individuals or are transported by birds to below other fleshy-fruit plants and pole trees (García 2007). It is precisely the protective canopy of pole trees, such as the Scots, black and aleppo pines, that offers one of the most effective sites for yew recruitment in the dry Mediterranean environment. Very few seeds are deposited outside of the tree canopy. Once dispersed, rodents, particularly wood mice, consume most of the seeds (Tittensor 1980, Hulme & Borelli 1996). Nonetheless, some seedlings do germinate during the second and third spring after dispersal. In general, the small seedlings have an extremely high mortality rate during the first years of life, mainly because of trampling or they are consumed by wild and domestic ungulates. However, a small portion survive, particularly those that have been lucky enough to germinate among nurse plants, i.e., thorny shrubs like Spanish sarsaparrilla and wild blackberries in the Catalan Pre-coastal Range (Camprodon et al. 2015) or holly in the Cantabrian mountains (García & Obeso 2003).

The path a yew seedling has to follow to become a healthy adult tree can be blocked by excessive light exposure or an excess of shade and competition (Schwendtner 2007, Ruprecht et al. 2010). Incidentally, an excess of shade can also inhibit flower and fruit production (Iszkuło & Boratynski 2006, Dhar et al. 2007). However, it can survive in dull environments as a companion tree, stretching its side branches in search of the light, in the hope that its shorter-living competitors fall into decay. And in terms of longevity, there are few trees that surpass the yew, capable of living for more than 2,000 years in natural conditions (Tabbush & White 1996), all the while able to produce vertical shoots that grow towards the light.

In terms of the landscape, apart from the microclimate and edaphic conditions, the distribution of fleshy-fruit producing woody plants depends on the dispersal processes and their determinants. And here, as mentioned by Schupp (1993) and Jordan & Schupp (2000), a diverse set of factors come into play: a) the location of the plants in extensive, or at least not excessively fragmented, forest stands; b) the density of fruit-producing plants and the concentration of fruit produced, allowing these to be easily visible and attractive to animals; c) the rotation of fruit-producing species that can attract seed dispersers and act as bait for less numerous or less healthy neighbouring plants, of the same or a different species; d) the types and abundance of dispersers that are present. These factors can also be applied to the yew and other zoochorous species in its habitat.

Long-distance dispersal and that which goes beyond the forest boundaries will depend on the ethology of the local animal species. While carnivores favour long-distance dispersal, increasing the likelihood of genetic exchange between populations (Levin et al. 2003), most birds are less likely to move to areas without forest cover (Morales et al. 2013), probably because of the added protection that the tree canopy offers against predators. This is so much the case that the fragmentation of montane forests has been indicated as the main cause of the yew's reclusion to areas of woodland that have suffered less deforestation (García 2015). In Catalan yew groves, most dispersal observed during the Life TAXUS project has arisen from concentrations of migrant song thrush and ring ouzel (Guixé et al. 2015). Only a scant proportion of seed was mobilised by sedentary birds (for example, robins, blackbirds, mistle thrush, jay and song thrush) and by carnivores (figure 2). Nevertheless, we should not underestimate the dispersive action of resident birds, to the benefit of the cohort of trees and shrubs of the yew groves, as has been detected in other Cantabrian environments (García 2016). Birds from open tree canopy spaces, such as the mistle thrush and ring ouzel, could play a decisive role in the propagation of yew beyond the boundaries of the forest.

Studies in Iberian yew groves have established different “dispersion landscapes” that vary depending on the year (García 2015) from the complexity of the network of fleshy-fruit producing plants and their dispersers. (figure 3). These landscapes vary, spatially depending on the distribution of plants and temporally, in line with good years of seed production, in the case of alternate bearing fruit plants. For example, in strong fruit-bearing autumns in clearings (hawthorn), birds disperse more seeds from inside the forest to these areas (which are more visited), a situation that may favour the expansion of the yew to open areas (figure 4). Fruit production in yew is more or less constant, occurring every year -although there are years that production is stronger than others- and the seeds are dispersed both by birds and mammals, which can cushion the effects of the differences between dispersal landscapes.

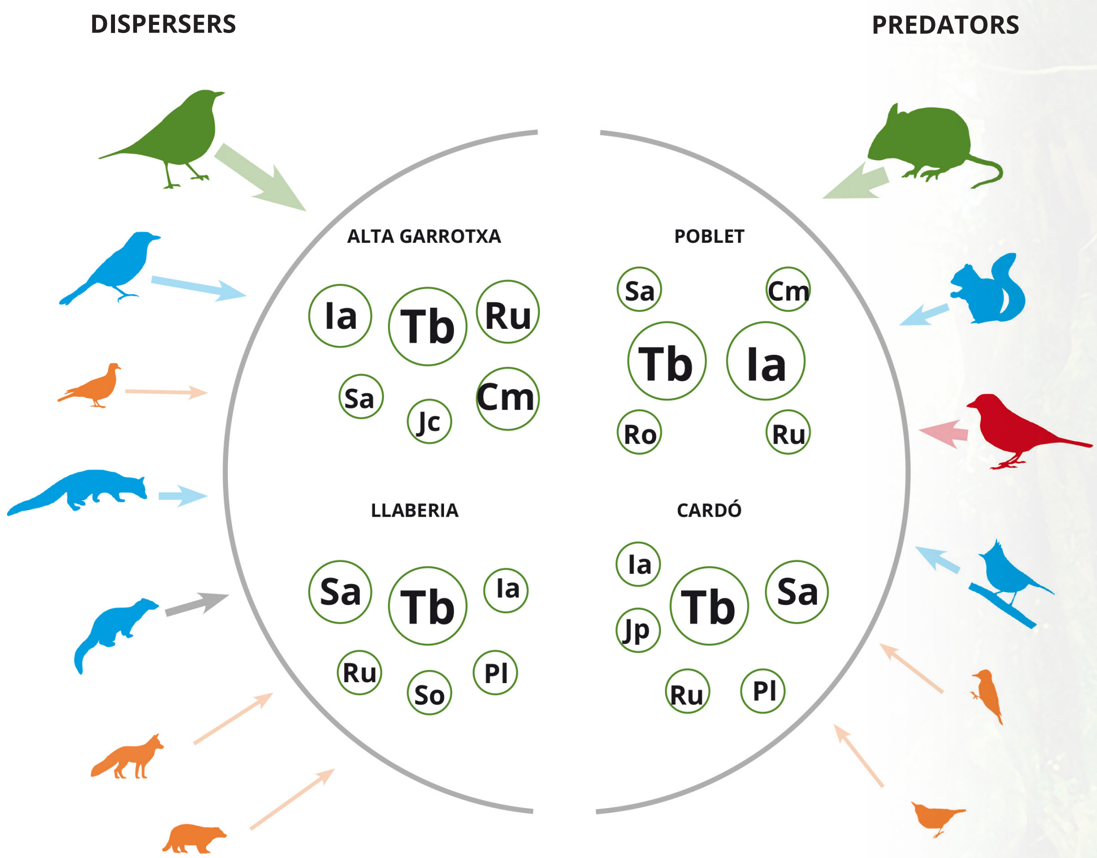


Figure 2. Composition of the network of trees and shrubs dispersed by animals in Catalan yew groves and main seed dispersers and predators, out of a potential total of 19 dispersers (12 birds and 4 carnivores) and 14 predators (11 birds and 3 rodents). The thickness of the arrows and size of the circles indicates the abundance of the species. Cm: *Crataegus monogyna*; Ia: *Ilex aquifolium*; Jc: *Juniperus communis*, Jp: *Juniperus phoenicea*, Pl: *Phillyrea latifolia*, Ru: *Rubus ulmifolius*, Sa: *Smilax aspera*, So: *Sorbusària / domestica / aucuparia*; Tb: *Taxus baccata*. Dispersers (from top to bottom): song thrush and other thrush, jay, woodpigeon, genet, beech marten, fox and badger. Predators (from top to bottom): wood mouse, squirrel, chaffinch, tits, great spotted woodpecker and Eurasian nuthatch. From Guixé et al. 2015. Drawings by Anna Gallés.

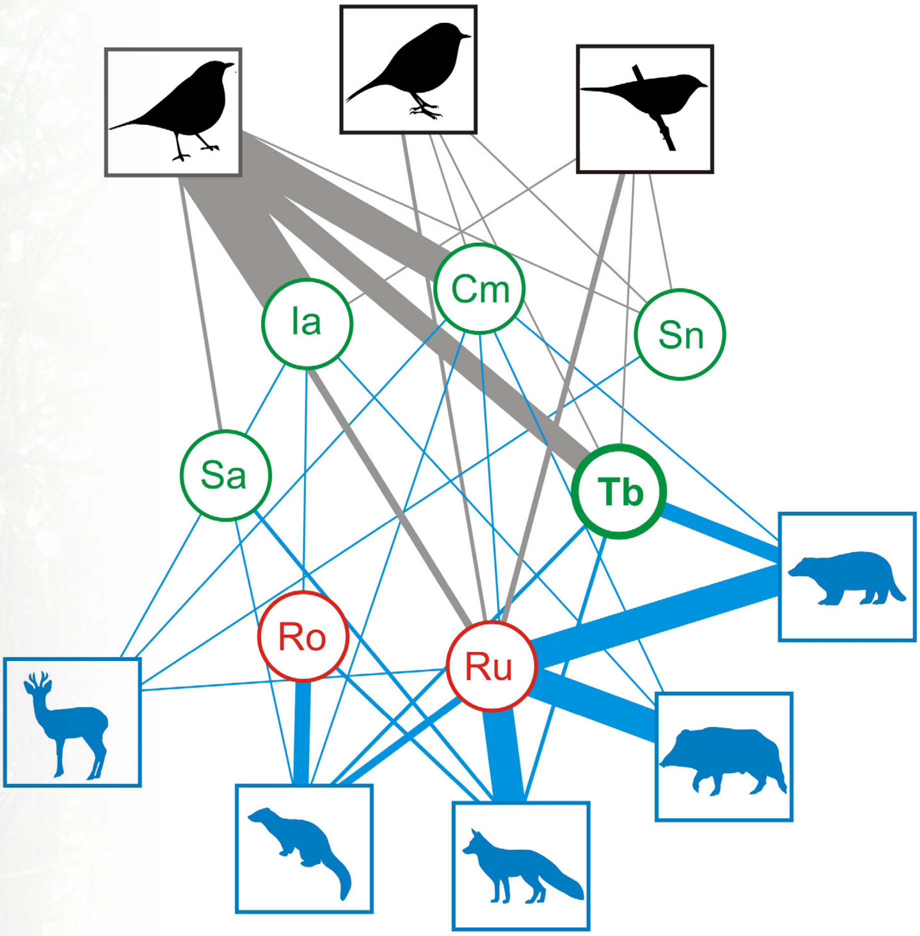


Figure 3. Network of seed dispersal interactions among trees (green; Cm: *Crataegus monogyna*; Ia: *Ilex aquifolium*; Sa: *Sorbus ària / aucuparia*; Sn: *Sambucus nigra*; Tb: *Taxus baccata*) and fleshy-fruit shrubs (red; Ro: *Rosa sp.*; Ru: *Rubus fruticosus / ulmifolius*) and birds (black; from left to right: thrush *Turdus* sp., robin *Erithacus rubecula*, warblers *Sylvia* sp.) and mammals (blue; from left to right: deer *Cervus / Capreolus; Martes* sp.; fox *Vulpes vulpes*; boar *Sus scrofa*; badger *Meles meles*) in secondary forests in the Cantabrian Mountains. The thickness of the linking lines is proportional to the proportion of seeds dispersed. Based on Martínez et al. (2008), Lavabre (2008), García et al. (2013) and Peredo et al. (2013). Illustrations by Anna Gallés.

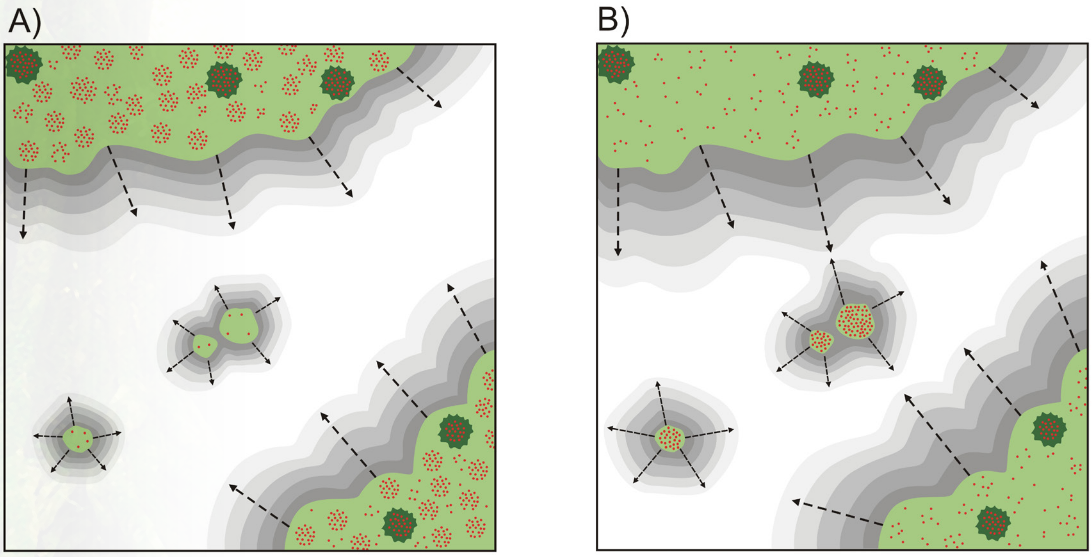


Figure 4. A) Representation of the distribution of yew seeds dispersed by birds from the edge of the tree canopy (light green, adult yews in dark green) towards unforested areas (pasture) in the Cantabrian Mountains, in a year where much fruit (for example holly, in red) was to be found in the forest. The grey bands and arrows represent seed density, which is lower the further away from the tree. B) In years with little fruit production in the forest, but with strong fruiting in isolated trees (for example hawthorn) seed dispersal covers a greater area of pasture and dispersal distances increase. Modified from Martínez & García (2014). Illustrations by Daniel Martínez.

3.4. Distribution in Europe, the Iberian Peninsula and Catalonia

The taxaceae family comprises 15 species, spread across 5 genera, most of which can be found in the Northern Hemisphere. In Europe, just one genus has been identified, which has a single species: the European yew, *Taxus baccata*, a slow-growing, long-living tree and surviving relic of the transition from the Cretaceous-Tertiary transition, around 66 million years ago (Hao et al. 2008). Pleistocene pollen traces indicate that its distribution was extended throughout the interglacial periods, when it was a more common and significant component of European forests than it is today (de Beaulieu et al. 2001, Müller et al. 2003, Koutsodendris et al. 2010). The yew seems to have colonised the continent from the east, with European populations divided into two highly genetically differentiated groups: one western and the other eastern. The Iberian populations would have been included within the western group, which includes southern and Western Europe, from the Iberian Peninsula to Greece and including Ireland and Great Britain; the eastern populations included central and Eastern Europe (Mayol et al. 2015). According to these authors, temperature seems to have played a more important role in this divergence than the availability of water during the warm interglacial periods.

The European yew is distributed from the south of Norway to the north of Africa, the Near East, Madeira and the Azores, in fragmented areas with scattered nuclei, especially in the southern area of distribution (Garcia et al. 2001, figure 1). The Caucasus Mountains set the boundary to the east and it is relatively common in the mountains of Turkey and northern Iran (Cortés et al. 2000). It has been wiped out in some central European areas and in others it is under imminent threat, as is the case in the Azores (Schirone et al. 2010).

In the Iberian Peninsula the yew can be found in almost all mountain systems, especially in the north, with the exception of the south-western quadrant. In the Mediterranean environment they are scarcer, but stands can still be found that are dominated by the yew in the Pre-Pyrenees, the coastal mountains of Catalonia, Alt Maestrat, Conca, Alto Tajo, the mountain ranges of the Valencian Region, the Central System and the Montes de Toledo (figure 2).

In the Catalan Countries it can be found in various places: from the Pyrenees (from the Vall d'Aran and Montsec, to the Corberes and Albera), followed by the coastal ranges (Olositanic and Catalanidic mountains), to the Dianic Mountains (like the Serra Mariola and Serra d'Aitana) and Serra de Tramuntana (Bolòs & Vigo 1989).

Despite the more or less extensive distribution of the yew as a scattered companion species in the forests of Central Europe and the Catalan Mediterranean region, as a plant community, its surface area is very low. Life TAXUS has been able to define up to 303 ha of forest stands with greater or lesser yew density. In most of these stands, the yew can be found in abundance as a co-dominant companion species or forms a subordinate tree layer. Just 25 stands with an average surface area of 2 ha, which add up to some 78 hectares, can be considered as yew groves, where the yew is dominant or forms a mixed community with broadleaf trees and conifers (table 1).

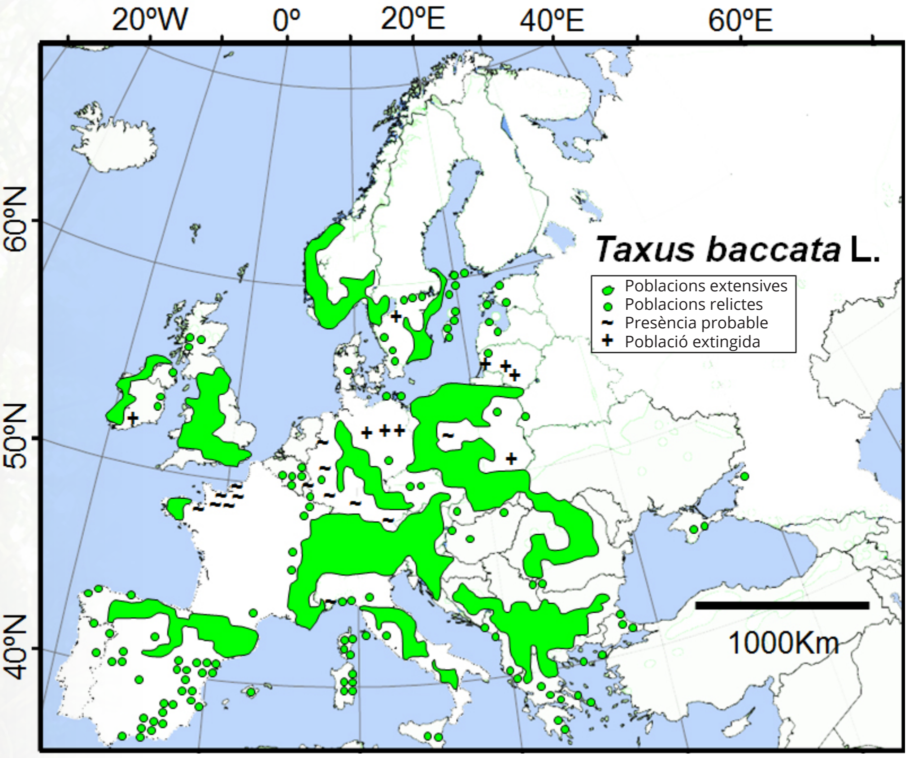


Figure 1. Source: Juan Carlos Linares. Revision from Jalasand Suominen (1973)

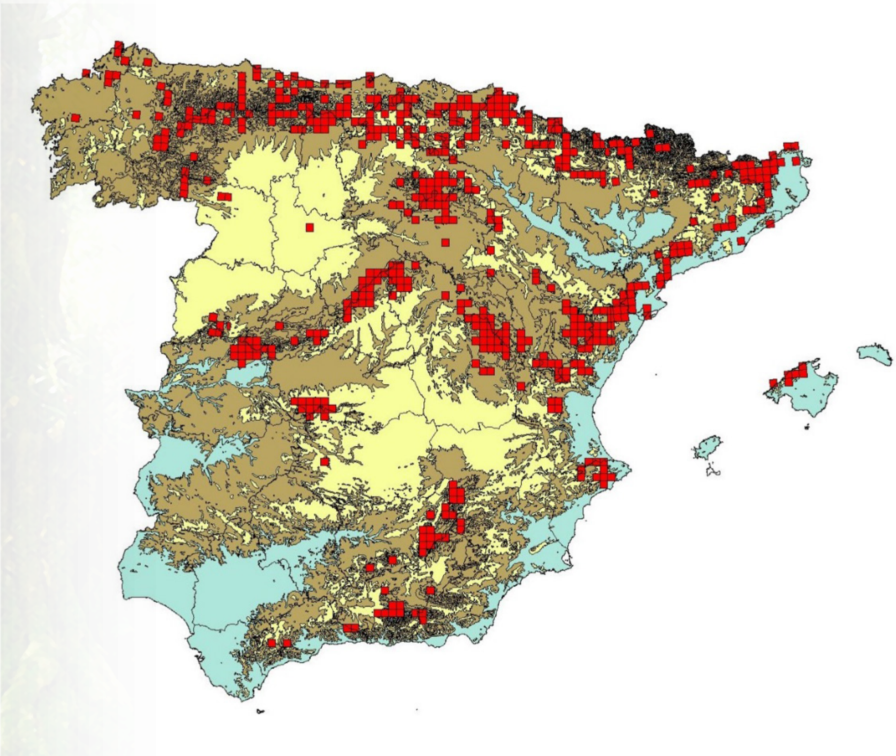


Figure 2. Distribution of the yew in Spain. Modified from Serra & Garcia Martí 2010

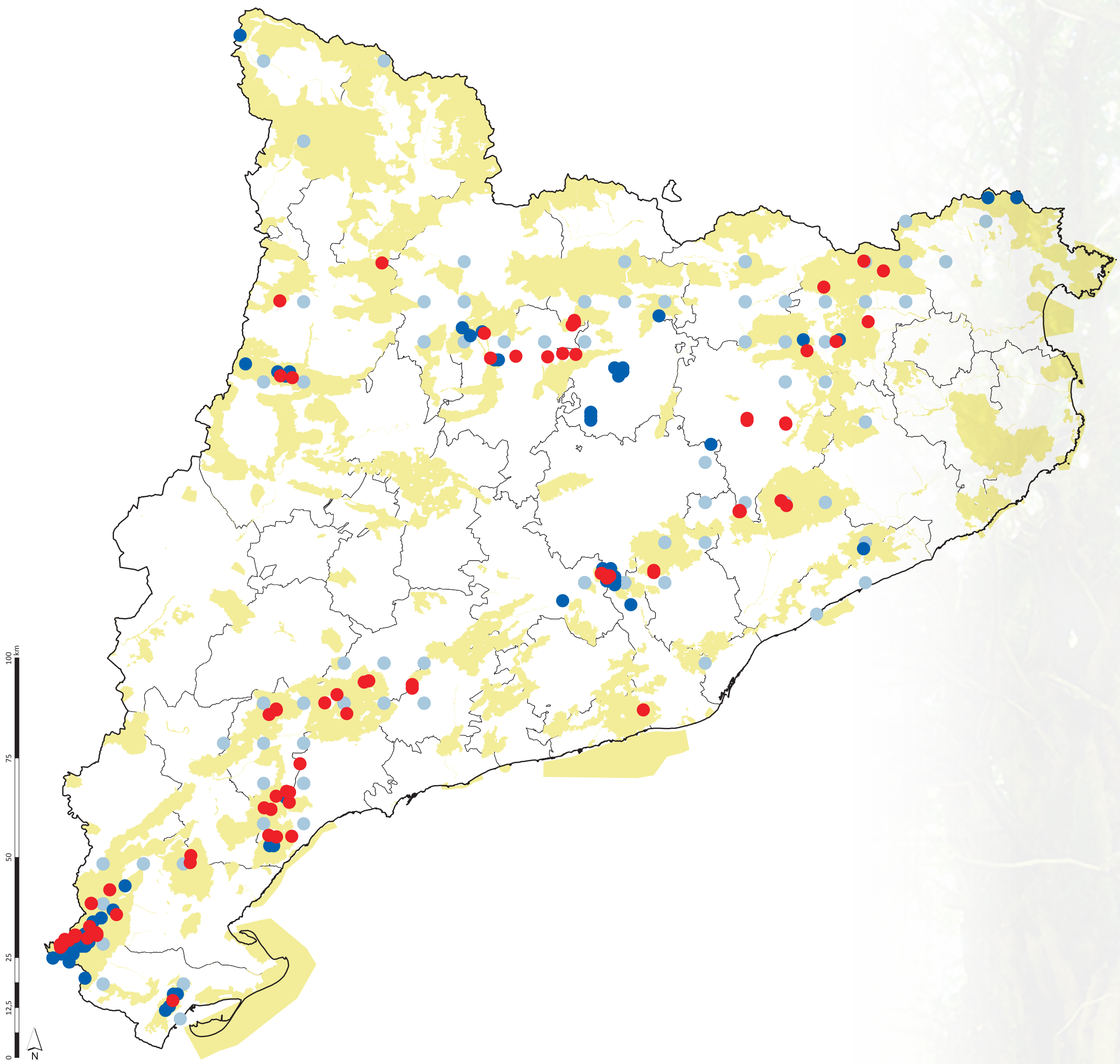


Figure 3. Source: CTFC & Generalitat 2016

Table 1. Yew groves and areas with a certain density of yew as a companion species, inventoried by Life TAXUS. Includes the surface area and SAC they belong to.

Area	SAC	Yew grove	Surface area (ha)
Alta Garrotxa	ES5120001. Alta Garrotxa-Massís de les Salines	L'Orri	4,9
		Llongarriu	1,3
		Misclós	8,2
Ribera Salada[1]	ES5130028. Ribera Salada	Obaga del Vilar	48,1
Savassona	ES5120012 Les Guilleries	Savassona	0,5
Turó de l'Home	ES5110001 El Montseny	Turó de l'Home	0,5
La Calma		Font del Vilar	0,5
Serra de Montserrat	ES5110012. Montserrat-Roques Blanques-Riu Llobregat	Canal dels Arínjols	2,2
Montsec	ES5130015. Serra del Montsec	Barranc de la Fontfreda	0,2
Bosc de Poblet[2]	ES5140008. Muntanyes de Prades	Baga de la Pena	85,0
		Barranc del Titllar	60,0
		Barranc dels Torners	6,3
Vall de Montblanc		Obaga de la Vall de Montblanc	7,0
		Pasquala i Ermita de Sant Joan	1,3
		Mas de Mateu	0,5
		Cogullons	0,9
Serra del Montsant	ES5140017. Serra de Montsant-Pas de l'Ase	Clot o Racó d'en Guasc	3,6
Serra de Llaberia[3]	ES5140009. Tivissa-Vandellós-Llaberia	Barranc del Teixar	3,8
		Escambellet	1,2
		Barranc de la Canyera	0,9
		La Mafla	0,5
		Mola de Perelló	0,5
		Los Borjos	0,5
		Canal Fosca	0,9
		Font de la Coma	0,5
		Clots - Tossetes	0,6
		Font de l'Avellar	1,4
		Canal del Roc	2,4
		Font de l'Om	2
		Bullidor	3,1
		Camí de Pratdip - Esquirol	3,3
		Coll del Guix	0,7
		Mas del Ramer	0,8
Serra de Vandellós[4]	ES5140009. Tivissa-Vandellós-Llaberia	Areas where present	6,6
Serra de Tivissa[4]		Areas where present	33,8
Rasquera	ES5140006. Serres de Cardó - El Boix	Cosp	6,1
Cardó-Benifallet[3]		Los Teixets	1,7
Els Ports[4]	ES5140011. Sistema Prelitoral Meridional	Areas where present	0,4
Total			302,8

[1] The dense part of the Obaga del Vilar yew grove covers a total of 2.5 ha.
[2] The dense parts of the yew grove cover a total of around 20 ha.
[3] The dense parts of the yew grove cover 17.8 ha., located only in the Serra de Llaberia.
[4] Areas where yews are present but do not form a dense habitat.

3.5. Historical uses and legal protection

The yew tree, once widely spread, has steadily fallen in number to the point of almost being in danger of extinction in Mediterranean areas. There is, therefore, a growing need to support their conservation and, furthermore, to increase their numbers in areas that are conducive to their growth (Iglesias et al. 1997). There is a great deal of archaeological evidence to show that, since neolithic times, yew forests and the wood from their trees, have been used to make tools and weapons, such as spears, axe and dagger handles, and, in particular, bows (Thomas & Polwart 2003). Coles et al. (1978) list up to 18 artefacts made from yew tree wood since prehistoric times in Great Britain and Ireland. The high concentration of the taxine alkaloid, which can be found throughout the tree (except in the aril), was used as a poison. Its use is documented as a dressing for arrowheads and as a method for committing suicide through its use as a beverage in Celtic, Celtiberian and Roman culture. In traditional medicine it was used in moderation as an anthelmintic, emmenagogue, abortifacient and analgesic, among other less common uses (Cortés et al. 2000).

Without doubt the best known use of the yew tree is for making bows in archery. Although a range of different woods has been used, particularly ash and Laburnum, yew tree wood gave the best results in terms of flexibility and strength. Various British monarchs (Edward IV, Richard III and Elizabeth I) decreed that yews had to be preserved and / or planted to maintain an adequate supply of wood for archery purposes, although the best wood came from continental Europe (Thomas & Polwart 2003). Northern Iberia was one of the suppliers (Cortés et al. 2000).

Besides being used to make weapons and being highly-valued in furniture making, there is no evidence to suggest a generalised use of the wood in modern history, nor even a specific practical forestry application, at least in Great Britain and the Iberian Peninsula (Thomas & Polwart 2003, Martí Boada pers. comm.), although as a species it can be found in certain old forestry agreements (Paniagua 1841). What has been recorded in northern Iberia, is the search for specific yews to build luxury furniture or competition bows for archery, preferably felled between the ages of 100 and 250 years for optimal wood quality (Cortés et al. 2000). However, at least during the beginning of industrialisation from the 19th century to the mid-20th century, yew forests were subject to complete or selected felling to obtain firewood and coal. This was not done specifically for the yew trees, but also for holm oaks and other woody species that could be taken from a single stand. In the coastal Catalan mountains today, many individual yew trees can be found with two or more shoots that must have been used for this purpose. Bygone forestry practices have been signalled as a determining factor in forest fragmentation, which isolated small nuclei of yew woodland and brought about the high level of genetic differentiation and endogamy in Montseny (Dubreuil et al. 2010). Anthropic factors (grazing, fires, forestry) may be behind the dramatic historical decline of the yew in Portugal. (Draper & Marques 2007).

In Catalonia there is a lack of old yews. Most of its centennial trees are solitary examples, with the exception of a few notable cases: the yew forest of Cosp (Serra de Cardó) and that of Barranc de la Fontfreda (Montsec). Old aerial images (flights from 1946 to 1956) of the yew forest stands in Catalonia show no change in the use of the land to indicate a recent colonisation of areas that had previously been cultivated or used for grazing. However, what can be observed, although only in certain cases, is a tree density that was lower in the 1940s and 1950s, indicating intensive exploitation and a possible associated silvopastoral use, as has been recorded in Cardó, Llaberia and Alta Garrotxa. Yew forests have certainly been used for grazing since ancient times in the Iberian Peninsula (Sanz et al. 2007, Schwendtner et al. 2007, Camprodon et al. 2015), a use that has also conditioned their structure. In the particular case of Cardó, the Cosp yew forest has survived thanks to its silvopastoral use for the Rasquera White goat. The yews served to provide shade, especially in the summer, and the shepherds would cut branches off to be used as browsing for the goats, which could tolerate the taxine. Hence, the people of Rasquera knew not to fell any of the yews (Roman Borràs pers. comm.). Their use as shade for livestock has also been observed in the yew forest of the Font del Vilar in Montseny (Martí Boada, pers. comm.).

In the 1960s, paclitaxel and docetaxel were discovered in the Pacific yew (*Taxus brevifolia*), complex alkaloids from the taxane class, present in all species of the genus, and which has extraordinary anticancer properties. In their commercial version (taxol and taxotere, respectively) they have been used since 1992 to treat ovarian, breast, lung, stomach and prostate cancer and the AIDS-related Kaposi sarcoma (information extracted from pharmaceutical leaflets). A major drawback is that many kilos of bark are needed to obtain small quantities of medication. Its clinical application caused the systematic destruction of North American and Asian yew forests. In 1988, the United States government banned the exploitation of wild yew as its pace was endangering their existence (Cortés et al. 2000). Overexploitation therefore became an issue for Asian yew forests, although not so much for European yews, their number having already dramatically declined. For example, more than 90% of Indian yews have disappeared (Hageneder 2011). As a result, given the demand for the different species and their high risk of extinction, since the 1990s large-scale plantations have been set up and research carried out into obtaining large quantities of taxanes using laboratory-based methods based on culturing yew plant cells.

The yew tree's suitability to pruning, its capacity for regrowth and resistance to plagues, disease and pollution, has led to its frequent use as an ornamental plant. Furthermore, its attractive shape and red fruits make it a highly popular species for gardeners (Vives, 2006). Another aspect that could be studied in the future is the influence that the commercialisation of Taxus baccata "fastigiata" from areas of Ireland (and other less common varieties) may have had on the genetics of the Catalan populations. In 1984, with the declaration of the yew as a protected species in Catalonia, its commercialisation was also banned, and tree nurseries therefore opted to reproduce this variety. Although it is far from being widespread, it would be interesting to observe whether or not it has caused genetic contamination in some of the populations.

A threat today is the inappropriate use of seeds and forest plants in conservation work. The use of yews of unknown origin, in environments containing natural populations, can cause serious problems in terms of genetic contamination. The introduction of specific regulations (see the box below) led to the delineation of regions of yew and regulation of repopulation practices, at least on paper. The potential usefulness of an examination of these regions of origin has been recognised, taking into account the distribution of the species, recent studies into genetic variability and the ecological characterisation of the different areas the tree inhabits (Vaquero & Iglesias 2007).

Legal protection

In Europe, the yew has either been wiped out locally or reduced to small populations in the last 4,000 years (Thomas & Polwart, 2003). This general decline continues today, even though in some regions an increase in tree cover has been recorded due to favourable local conditions (Carvalho et al. 1999, Seidling 1999, Svenning & Magård 1999, Thomas 2015). This has prompted debates on the future of the yew and yew groves (Dhar et al. 2006, Iszkuło et al. 2009, Linares 2013, Devaney et al. 2014). The yew has therefore been designated as a protected species in different European countries (Hageneder 2007) and as a habitat it has been classified as a conservation priority in the European Union.

The Mediterranean yew forests are included as one of the priority natural habitats(*) for the European community, the conservation of which requires the designation of special areas of conservation (SAC) in the European Union: habitat 9580* “Mediterranean forests of Taxus baccata” (Habitats directive 1999/105/CE).

In the Spanish state the production and commercialisation of seeds and yew plants for their use in forestry is regulated in Spain by R.D. 289/03 (transposition of the Habitats Directive).

In Catalonia it is a protected species under the Order of 5 November 1984, which prohibits the tree’s commercialisation, as well as its harvesting, cutting or uprooting, or that of any of its parts, including the seeds.

Figure 1. The oldest and most complete known reproduction of a bow, recovered from the neolithic site of La Draga (Mesolithic, 7250-7050 years BP).

Figure 2. The Neolithic period, around 7,000 years ago, marked the beginning of agriculture and animal husbandry, and hunting was still widely practiced. There was a large amount of fauna and many old-growth forests. Yew wood was the most highly valued for making bows and other tools until after the Middle Ages.

Figure 3. After the 8th century and throughout the industrialisation process the use of the yew reached its peak. Agriculture and animal husbandry occupied vast extensions of land, especially in the mountains. The forests were used intensively for wood and coal and most of the yews and old-growth forests disappeared.

Figure 4. During the second half of the 20th century, society became more urbanised and some of the forest-based practices were abandoned. Forests recovered land, but competition, over-grazing, large-scale fires and genetic isolation brought the yews under threat. The loss of biodiversity created a need for the sustainable management of the rural environment, which would allow the natural habitats to recover in a way that was compatible with their exploitation.

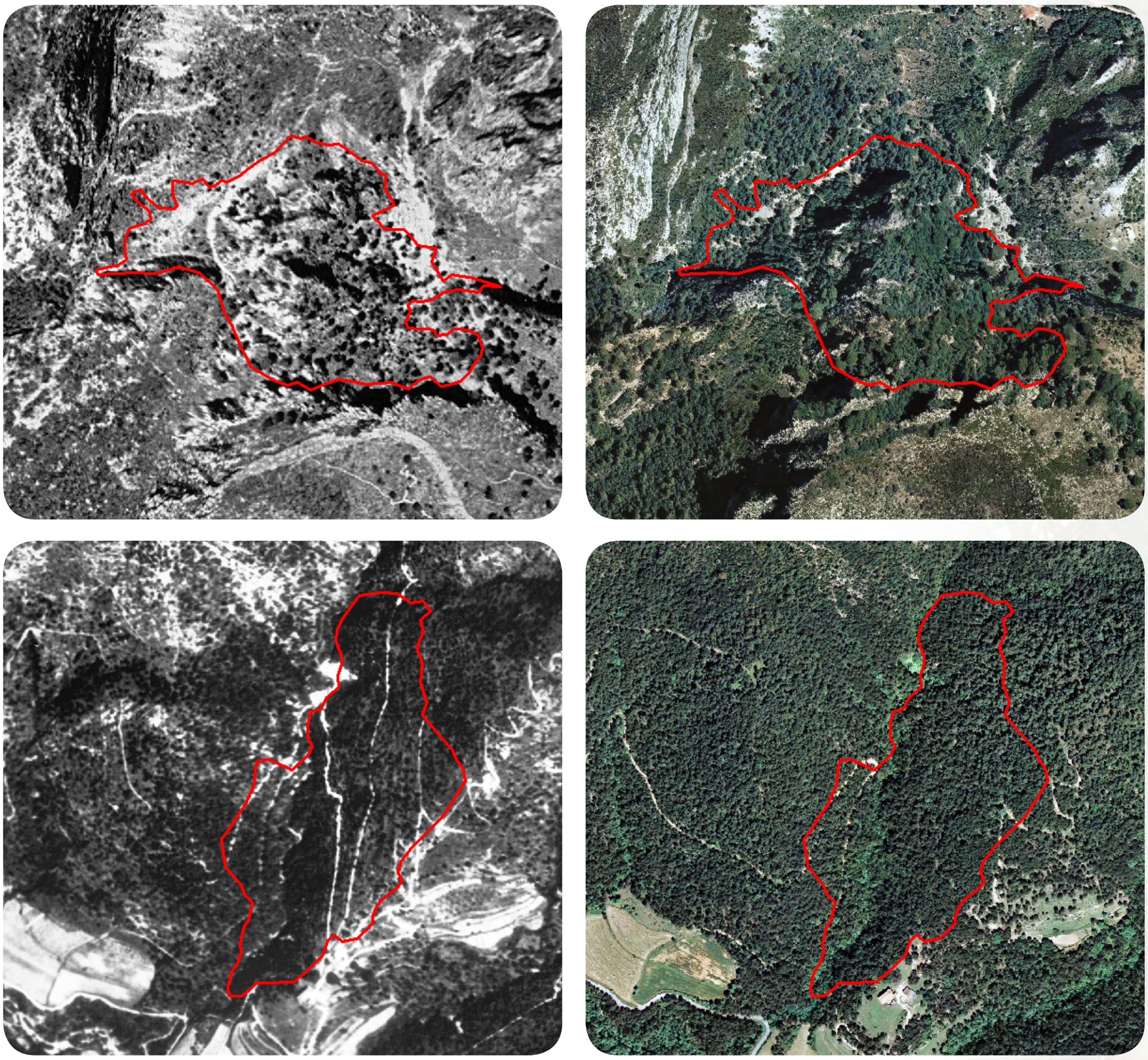


Figure 5. Comparison of the woodland cover of the Cosp yew forest (Serra de Cardó) and Miseclòs (Alta Garrotxa) in the 1956 and 2015, indicating a reduction in tree density in yew stands.

4. ENVIRONMENTAL ISSUES ASSOCIATED TO YEW GROVES

4.1. Competition

The yew is a shade tolerant tree (Thomas & Polwart 2003). The seedlings and saplings seem to benefit from a certain amount of bush cover, which defends them against herbivores, and from tree canopies, which protect them from dry weather in summer. However, various studies suggest that closing the crowns in the adult phase is one of the main causes of slow growth, a lack of height and girth, low levels of fruiting and mortality in northern and central European forests (Svening & Magärd 1999, Iszkuło & Boratynski 2004; Amalesh et al. 2007, Dhar et al 2007, Ruprech et al. 2010). The probability of sexual reproduction is seen to increase greatly with the diameter of the crown and is also favoured in areas where crowns are more visible (Svenning & Magard 1999). It has also been suggested that closing the crowns may be responsible for greater consanguinity (Chybicki et al 2011), which may compromise the future reproductive viability of populations.

Stagnating yew populations have also been observed in mixed Mediterranean broadleaved or conifer forests in Iberian populations (Camprodon et al. 2015), to the extent that excessive competition to a slow-growing tree like the yew has become one of the main problems for establishing dense yew woodland. For example, in the Serra de la Llaberia (Camprodon et al. 2010) or the Bosc de Poblet (Vives 2006) the stands with a high density of yews are dominated by pines and holm oaks or mixed holm oak-pine woodland with a tree density varying between 1,300 feet/ha and 3,200 feet/ha, including saplings. A very high percentage of yew trees are subjected to mechanical pressure, light reduction in the crown and competition for water (figure 1). Yew trees with uncovered crowns however are seen to be healthier and more balanced to a statistically significant extent as compared to covered or semi-covered yews (Camprodon et al. 2010).

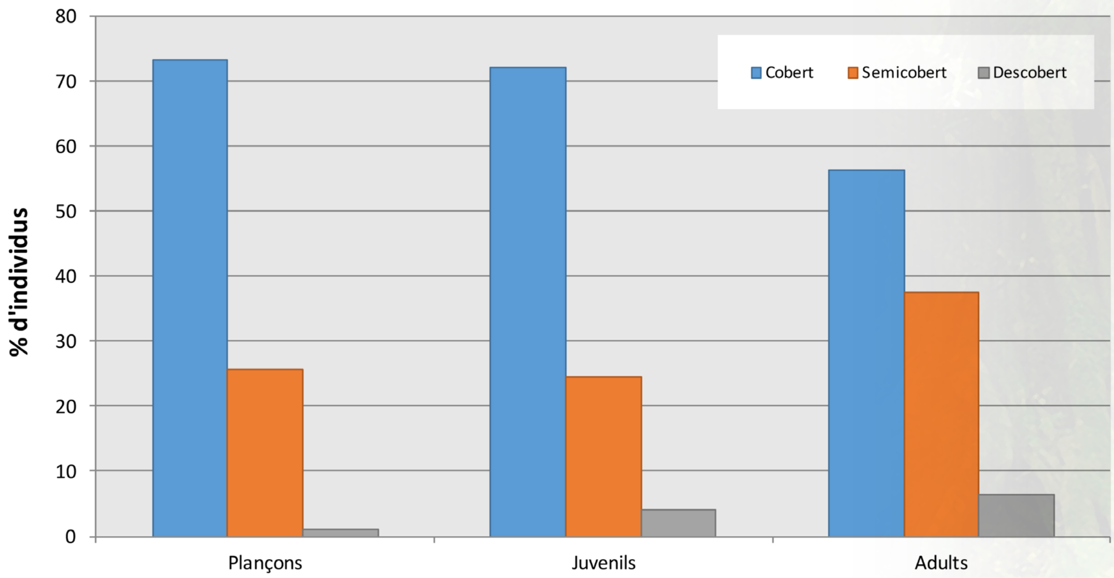


Figure 1. Covering of individual yew trees according to their age by other woody species in the Serra de Llaberia. Source: Camprodon et al. 2008.

We define three types of competition to the yew:

- **Mechanical:** other tree crowns come in contact with the apical shoot, so that this no longer dominates. As a result, the crown tends to flatten and stops reaching for the canopy.
- **Light:** other tree crowns reduce the direct or diffuse light for the yew. This often leads to the tree bearing little fruit and the lateral growth of branches in search of light.
- **Water:** if there is little room between tree roots it is difficult for the yew to absorb water, leading to water stress.

As a consequence of intense mechanical competition, yews lose apical dominance, their growth is slowed, they don't fruit and are eventually relegated to merely accompanying the surrounding plant life; the young trees can die due to a lack of light or, at best, growth may be stalled until a disturbance frees them from their neighbours (figures 2 and 3). Likewise, certain major symptoms of decay have been observed, such as the existence of dry leaves or branches, which may be due to water stress caused by the dry periods of recent years. In fact, the existence of carbon isotopes (δ13C) in the leaves of young yews suggests greater water stress the larger the basal area of the surrounding trees. At the same time, they also indicate that the stress is greater the less tree canopy there is, suggesting a possible facilitating effect of a balanced canopy of other trees, which helps to reduce transpiration (Casals et al. 2015; Ríos et al. 2015).

Figure 2. Shape of a yew crown where there is an excess of interspecific competition. La Canyera (Serra de Llaberia). Photo: Jarkov Reverté.

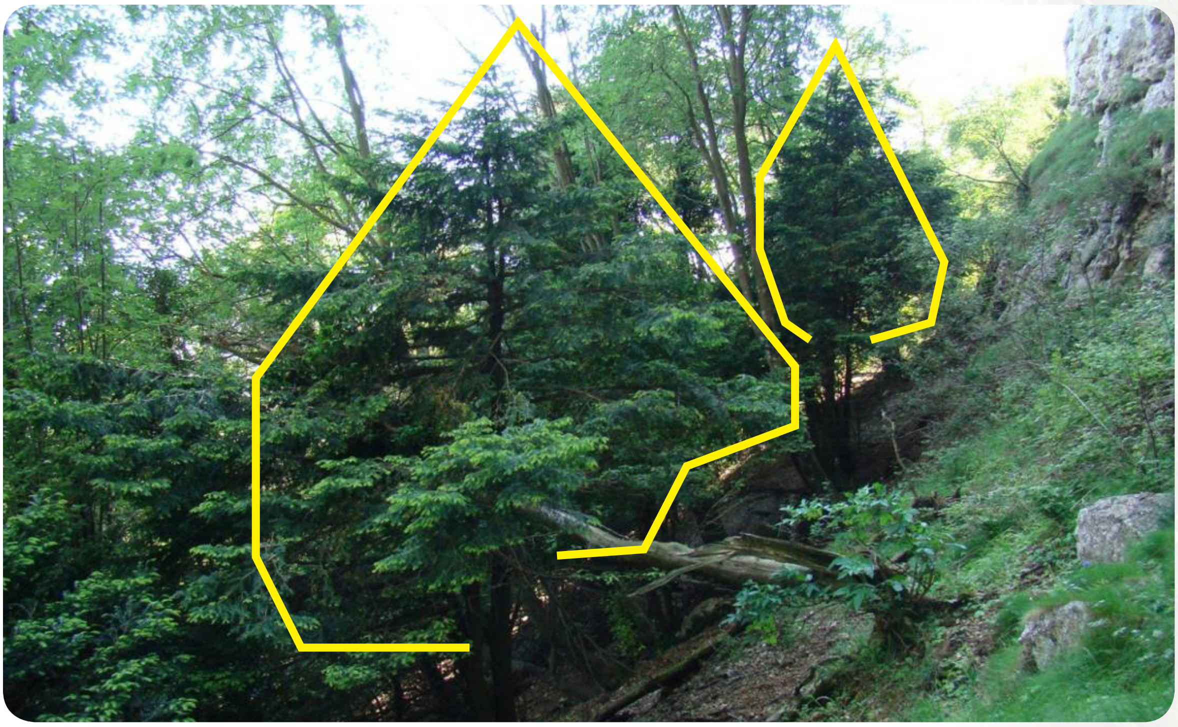


Figure 3. Conical shape of yew crowns with apical dominance, unhindered by interspecific competition. Mola de Colldejou (Serra de Llaberia). Photo: Jarkov Reverté.

Regenerated yews are especially tolerant to shade and grow well surrounded by understory shrubs and bushes. It has been shown that woody plants or shrubs, like the holly, common smilax or elmleaf blackberry can serve to provide the young yews with humid microenvironmental conditions and protection against herbivores (García et al. 2000, García & Obeso 2003). However, when the yew reaches juvenile age, an excess of mechanical cover by vines and other understory plants can obstruct its apical growth. (figure 4).

Figure 4. Young yew covered by shrubs, a balance between protection and competition. Baga de la Pena, Bosc de Poblet. Photo: J. Camprodon.

For its part, excessive shading of the tree stratum can cause a lack of recruitment, whether because it reduces the production of seeds (Ruprecht et al. 2010, Dhar et al. 2007; Iszkuło & Boratynski 2006) or because only excessively low levels of light can penetrate. For example, in highly dense monospecific stands, like the central part of the Miseclòs yew forest (la Garrotxa), there is a total lack of regenerated yews under the dense canopy (averaging 80% crown cover), where the yew represents 66% of the canopy, with respect to that of the other species (mainly holm oak and scots pine). In contrast to this, it has been noted that the yew expands after the canopy is opened (Svenning & Magärd, 1999, Caritat & Bas 2007).

In conclusion, a balanced density of crowns, with a canopy density of between 50 and 70%, could be ideal for maintaining healthy yew populations with the capacity for recruitment. The selective opening, therefore, of the tree canopy with the aim of reducing competition has been indicated as a key factor in the conservation of yew forests in the Mediterranean mountains (Linares 2013).

4.2. Diseases and pests

Fungal infection forms part of the natural dynamics of forests. In comparison with other trees, there are relatively few species of fungus that infect the yew (table 1). A total of 258 species of fungi have been identified in *Taxus baccata* as compared with 2,200 species in beech trees and oaks (Hageneder 2007). The growth of fungi is very closely related with the permeability of the wood, which makes it easier for hyphae to penetrate and also affects the availability of water and gases. For example, the permeability of the *Thuja plicata*, a tree native to America, is a thousand times higher than that of the yew (Hageneder 2007).

Although the yew is an especially resistant species to attack from fungi, conditions of stress, especially those caused by drought, can be conducive to fungal infection and can even be fatal for yews. This has been observed in different yew forests, such as in La Garrotxa, where yew deaths were recorded from root and branch damage caused by the *Armillaria* fungus after several years of drought, while other partially affected trees recovered after pruning treatment (Caritat & Bas 2007).

The *Phytophthora* sp. fungus causes serious disease in the roots of the yew and *Nectria radicicola* can even kill seedlings (Strouts 1993). Prominent among the parasitic fungi is *Phellinus chysoloma* which enters through wounds and attacks the cambium (Hageneder 2007). In old trees, among the fungi that are most commonly observed are *Laetiporus sulphureus* and *Heterobasidion annosum* which have eye-catching colours and affect the wood of the tree (Cortés et al. 2000).

Figure 1. A yew killed by *Armillaria* sp. In the yew forest of Miseclòs (Alta Garrotxa). Photo: Jordi Camprodon.

Figure 2. *Armillaria* sp. mycelium in the roots of a yew. Serra de Llaberia. Photo: Jarkov Reverté.

Figure 3. The presence of dry twigs on the tree can be a symptom of fungal attack. Bosc de Poblet. Photo: Pere Casals.

In general, there is very little information regarding the specific pests that yews are vulnerable to. The species is relatively resistant to attack, thanks to the presence in the leaves and roots of an insecticidal substance called ecdysone, which can be fatal if applied to the skin. (Takemoto 1967 & Nakanishi in Cortés et al. 2000).

Some of the insects and acari that can attack the yew are (Thomas & Polwart 2003):

- *Taxomya taxi (=Cecidomya taxi):* small diptera that lays its eggs on the leaves of the yew. When the larvae hatch they feed from the cell juices of the buds and form galls in the form of small cones, observed in different yew stands in northern Catalonia.
- *Liparis monacha:* moth which during its caterpillar stage eats the leaves.
- Parthenolecanium pomeranicum and Chloropulvinaria floccifera are among the coccidia that feed on the yew. They produce a sugary liquid in the branches and leaves that favours the presence of certain fungi.
- *Cecidophyopsis psilaspis.* This acari is considered a serious pest for yews in northern and central Europe. Its effect on trees ranges from a light reddening of the scales on the apical buds, to the acute hypertrophy and total necrosis of the bud. The hypertrophy of apical buds causes them to fall from the tree and, as a consequence, new plant growths form from lateral shoots, leading to erratic and asymmetric growth. This acari has a direct life cycle since the eggs, larvae, nymphs and adults can all be found simultaneously throughout the year (Mitchell et al. in Viñas 2004).

Table 1. Different parasites detected in *Taxus baccata*.

FUNGI	**Affected area**	**citations**
Nectria radicola	seedlings	Thomas 2003
Nectria coccinea	bark	Cortés et al. 2000
Microspora taxi	bark	Cortés et al. 2000
Physalospora gregaria	branches	Cortés et al. 2000

Phellinus chysoloma	wood	Hegeneder,2007
Phytophtora sp.	roots	Strouts 1993
Armillaria sp.	roots, branches	Caritat 2013
Aleurodiscus aurantius	wood	Hegeneder 2007
Laetiporus sulphureus	wood	Hegeneder 2007
Heterobasidium annosum	wood	Cortés et al. 2000
Diploida taxi	wood	Vegh 1987
Rhizoctonia solani	roots	Vegh 1987
Coniothyrium sporulosum	branches	Vegh 1987
Pestalotiopsis funerea	leaves	Vegh 1987
ACARS		
Cecidophyopsis psilaspis	buds	Hegeneder 2007
Eriophyes psilapsis	leaves, buds	Siwecki 2002
INSECTES		
Liparis monacha	leaves	Cortés et al. 2000
Cecidomya taxi	buds	Moro 1988
Oligotrophus taxi	buds	Cortés et al. 2000
Parthenolecanium pomeranicum	leaves	Soria 1996
Chloropulvinaria floccifera	leaves	Soria 1996
Lineaspis striata	leaves	Soria 1996
Carulaspis juniperi	leaves	Soria 1996
Chrysomphalus dictyospermi	leaves	Soria 1996

Figure 4. Gall caused by *Taxomyia* taxi, a diptera specialized in parasitising the yew. The larva penetrates the bud and settles into a growth point, which produces between 60 and 80 scales, like a small artichoke. The full cycle takes 2 years. Galls remain empty on the host plant for several years. Photo: Jordi Bas.

4.3. Damage from herbivores

Grazing herbivores, whether domestic or wild, together with fire, could be considered to be two of the key factors of both the biological and landscape structure of Mediterranean ecosystems (Fabbio et al. 2003). Mediterranean landscapes, therefore, cannot be fully understood without considering the, mainly agropastoral, human activity which has taken place there since antiquity structuring and shaping its mosaic of plant life and diversifying its composition (Le Houérou 1990, Montserrat & Fillat 1994). Silvopastoral activity has an important role in the way Mediterranean ecosystems function, especially in the conservation of certain species or ecosystems and in reducing fire risk (Casals et al. 2009, Taüll et al. 2011 a, b).

The marked seasonality of the Mediterranean climate has given rise to the need to diversify grazing resources, whether through transhumance towards cooler regions in the summer, upward and downward displacement in mountainous areas, or making use of the diversity of formations on a local scale. The forest provides animals with a cooler environment at the height of the summer, green vegetation and fruit. Browsing on shrubs offers practically no proteins at all, except for the fruit of certain leguminous plants, and similar fibre content to straw. The microelements they provide, however, seem to be of importance.

1. Browsing on yews

However, grazing can have an undesired impact on certain ecosystems or their components. Therefore, many studies conducted on yew populations, both central European (e.g. Hulme 1996, Thomas & Polwart 2003) and Mediterranean (e.g. Farris & Filigheddu 2008, Piovesan et al. 2009), indicate that browsing on juvenile yews is one of the main causes for the collapse in their populations. Despite it being a toxic plant, fatal for humans, ruminants have a strong resistance to taxanes to the point of having a large appetite for the green yew leaves.

The impact can be greatly detrimental, leading to the decay and death of seedlings and juveniles. In the Iberian Peninsula, it constitutes one of the main problems for the regeneration of the species (García et al. 2000). It is a well known fact that wild deer and goat are drawn towards yews. In Guadarrama, for example, severe degradation has been detected due to excessive herbivory, caused by the overpopulation of the reintroduced wild goat (more than 4,000 individuals). Just 11.7% of the trees recorded in inventories were not affected. 29.4% are at greater risk of disappearing in the short term (Bernal 2015). In some areas, where the yew has practically disappeared due to intensive grazing, the reduction in grazing pressure has facilitated a recolonisation of the yew on what was formerly grazing land in the Serra de Urbasa and Serra de Lokiz (Schwendtner et al. 2007). In Catalonia, the damage caused by livestock is greatly increased when the yew are not protected by thorny shrubs. The impact from goats is particularly severe in the Serra de Llaberia and Serra de Cardó (figure 1), while that caused by cattle (figure 2) has strongly affected certain populations in Alta Garrotxa (Camprodon et al. 2015).

2. Key factors of yew browsing

Among the parameters that affect browsing of a given plant species, and in particular the yew, the following are considered of importance:

- **Woodland structure**

The woodland structure, both in the tree and shrub layers, influences the establishment of new yew seedlings. The presence of fruit-producing trees or shrubs can attract animals, which, after consuming yew berries, can excrete the seeds closeby. At the same time, the plant, especially if thorny or dense, can provide physical protection and facilitates the survival of yew seedlings (García et al. 2000). The woodland structure and composition also affects livestock and its preference for one plant species or another.

- **Livestock preference**

Not all plants are consumed in the same way by livestock (table 1). Among many variables, the consumption of a species also depends on the other shrub and herbaceous species in the stand. In general, the greater the diversity and cover of palatable species, the lesser the impact is likely to be on a given species. The palatability of a plant species is a broad concept, which brings into play the animals' preference, nutritional value, digestibility, the presence of toxic compounds, etc. Some species, therefore, that may be heavily browsed may not be particularly palatable.

Table 1. Shrub species in yew populations in Catalonia and livestock preferences

Nurse species	Preference for livestock
Amelanchier ovalis	Consumed by sheep and goats; young, leaf pubescence
Cornus sanguinea	Consumed by all kinds of animals
Crataegus monogyna	Little consumed; thorny
Ilex aquifolium	Consumed by goats; very hard and thorny leaves
Juniperus communis	Not consumed; needle-like leaves and dense foliage
Juniperus phoenicea	Not consumed, dense foliage
Ligustrum vulgare	Consumed by all kinds of animals
Phillyrea latifolia	Consumed by all kinds of animals
Prunus spinosa	Consumed by goats and, to a lesser extent, sheep; needle-like stems.
Quercus ilex	Well consumed by all kinds of livestock
Quercus coccifera	Heavily consumed by goats and little consumed by sheep; hard and thorny leaves
Rhamnus alaternus	Consumed by sheep and goats
Rosa sp.	Not consumed at all; stems with thorns
Rubus sp.	Consumed after budding
Taxus baccata	Consumed
Viburnum lantana	Consumed by all kinds of animal

- **Instantaneous stocking rate**

This indicates the number of animals (livestock) per unit of surface area (UBM ha-1) at a given moment. This variable affects browsing. The higher the rate, the greater the probability the yew will suffer browsing. The annual rate is not considered to be a suitable indicator to assess browsing, as in a given area there could be areas where browsing pressure is particularly heavy and others where pressure is moderate or light.

- **Livestock routines and infrastructure**

Livestock activity includes grazing, rest and drinking. There is an important distinction between livestock directed by a herder, that can be led away from areas with an abundance of yews, and herds kept within fenced areas, where the animals create their own routines. The location of watering points are key for changing the animals' behaviour in a given area, as these increase the presence of livestock nearby and paths are created between grazing areas and these points.

Figure 1. Yew seedling browsed by goats. Photo: Jordi Bas

Figure 2. Adult yew browsed and broken by cows but still growing new shoots. Photo: Jordi Camprodon.

4.4. Wildfires

In today's context of global change, the abandoning of the rural environment and woodland areas is leading to a homogenisation of the landscape and an expansion and accumulation of biomass in forests. We can, therefore, predict an increase in the occurrence of forest wildfires and also in their intensity (Piqué et al. 2011). This problem increases in magnitude as the climate change brings more severe droughts, with the increased availability of fuel and elevated chances of fire ignition (Piñol et al. 1998, Pausas 2004).

Forest wildfires, a major natural disturbance, are a real threat to a large part of the forests and yew groves in the Mediterranean and sub-Mediterranean areas (Piovesan et al. 2009, Camprodon et al. 2015). The prevention of wildfires is therefore one of the main goals in the management of Mediterranean forests. The integration of fire in forest management has been undertaken on different scales, and the integration of the risk of large forest fires (large fires that actively spread through tree canopy with great intensity and which are often beyond the capacity of direct extinction actions) has been a priority in Catalonia's forest policy.

Forest management for the prevention of large forest fires (LFF) is based, on the one hand, on the analysis of the main factors that condition fire behaviour and spread (topography, weather and fuel) and, on the other, on the study of past fires and defining different fire types and their models (Costa et al. 2011). In addition, forest management is complemented with forest-related defence infrastructure, normally defined at massif scale (according to the General Plan of Forest Policy), either aimed at modifying the behaviour of potential forest fires or increasing the effectiveness of extinction actions and ensure safety for firefighters.

Nonetheless, when it comes to reducing the risk of wildfire specifically in small yew stands or disperse yew tree populations, forest management action for preventing large forest fires has to be complemented with actions designed at stand scale. These actions are focused on the modification of fuel as a determining factor of fire behaviour on this scale and, more specifically, on its arrangement within the space: forest structure (Rothermel 1983, Bilgili 2003, Graham et al. 2004). Based on the analysis of how forest structure influences fire spread, wildfire prevention management at stand scale is aimed at creating and maintaining forest structures that are less vulnerable to generating and maintaining active crown fires (Piqué et al. 2011).

As a general rule, and considering the most probable fire types for each area, forest management partly aimed at wildfire prevention proposes silvicultural treatments to create sufficient discontinuity between the different strata in which the vegetation is divided, vertically and horizontally (Beltrán et al. 2011, Beltrán et al. 2012). In the case of yew groves, the most frequent action is selective shrub clearings to eliminate the shrubs that act as ladder fuel and reduce the covering of surface fuel, together with light selective thinnings that eliminate trees that compete with the yews in the dominant stratum, normally pines and quercines (holm, downy and mediterranean oak).

These actions should be carried out both in yew groves, with less intensity, and perimeter areas, with greater intensity. It is also advisable to undertake similar actions to reduce the structural vulnerability in stands located in strategic management points (SMP), according to the definition

[1] Approved in Catalonia by Government Accord GOV/92/2014, of 17 June, under which the General Plan of Forest Policy 2014-2024 is approved.

of Costa et al. (2011), which can modify the behaviour of wildfires that may potentially affect yew groves (figure 1). This, therefore, improves forest fire prevention in yew groves.

Finally, it is interesting to note the yew's capacity to resist fires, particularly adult yews (figures 2 and 3). The yew has an impressive capacity for regrowth and can even lose a large part of its original trunk and continue to grow laterally or from part of the stump. But this resistance may not be sufficient if the area's fire regime varies and more wildfires arise with shorter recurrence intervals or greater intensity. In these cases regeneration may be affected and small populations may collapse for many years. At the same time, those yews that are most affected are left in a weakened state and are more vulnerable to secondary effects from fungi or insects, which will further worsen their health.

Figure 1. A stand dominated by Black pine and located in an SMP identified as potentially affecting the yew forests of Llaberia, where action has been taken to reduce structural vulnerability: selective shrub clearing and light thinning from below. Photo: Mario Beltrán.

Figure 2. Old yew with fire damage but still alive in the Cosp yew forest (Serra de Cardó). Photo: David Guixé.

Figure 3. An old yew that was struck by lightning in Montsec Mountain. Photo: David Guixé.

4.5. Soil erosion

Soil is the layer that sustains life in the ground; sustain being the operative word, as the soil provides the physical support for plant life to lay its roots and also the nutrients and water for its development (figure 1). The formation process of soil is so slow that its degradation from erosion, pollution or surface sealing (with asphalt, for example) is irreversible on a human scale. Soil erosion refers to the transportation of soil away from where it was formed, where it sediments in a destructured way, losing a large part of its function. In the Mediterranean Basin, erosion is often caused by water, although wind can be a more significant agent under certain circumstances. In addition, soil erosion especially affects the surface layer of the soil which is often the richest in nutrients and organic matter. It is evident that erosion, although a natural phenomenon, especially on a geological scale, is accelerated by human action.

The risk of water erosion depends essentially on the following factors: the energy of the water, the length and gradient of the slope, and the characteristics of the soil and covering vegetation. The precipitation model in the Mediterranean is typified by its irregularity and the repetition of periods of very heavy rainfall. Since the Mediterranean yew forests often grow in conditions where there are steep slopes and at altitudes where there is a high frequency of torrential rainfall, they are, by nature, exposed to potentially intensive erosive processes.

The loss of soil cover, affecting the vegetation or the plant litter that covers it, constitutes the main factor for triggering erosion caused by human activity. Without cover, the impact of raindrops disintegrates the topsoil and forms a crust that hinders water infiltration (Llovet & Vallejo 2011). When this happens on a slope, there is a high level of water runoff along the surface, which, as it gains speed, can increase the transport of particles and soil erosion. The presence of vegetation reduces the intensity of the raindrops and lessens the soil drag.

Impact, directly or indirectly related to human activity, which can trigger erosive processes in yew forests includes:

1. Forest fires

Very severe fire on steep slopes can greatly increase the risk of erosion due to both the direct effects of the fire and the loss of plant life that cushions the impact of the rain and retains the soil between its roots. (Shakesby & Doerr 2006). On a steep slope, the areas affected by fire are not only subject to the uprooting process, but also the loss of soil can affect the future regeneration and establishment of yews and other species that share the habitat.

2. Forestry work

When carrying out conservation work the utmost caution must be taken (Camprodon et al. 2015). For example, when using machinery or taking precautions not to remove competing trees that are rooted in banks or steep slopes, as these can contribute to retaining the soil in conditions where the risk of soil erosion is high. Deforestation or where trees have been dragged, or ground skidding, tracks or new footpaths opened can destabilise banks or slopes that can have a knock-on effect on neighbouring trees.

3. Overgrazing

Areas where livestock pass can trigger erosive processes due to the disintegration of the topsoil and its compaction under the animals' feet, which hinders rainwater infiltration, or due to the decrease in vegetative cover due to animals browsing vegetation, the roots of which help to retain banks and slopes. Grazing, however, can be harmless if it is done sensibly, limiting the grazing to the load capacity of the soil and vegetation.

4. Human presence

The frequent transit of people, on foot, jogging or riding bikes compacts the soil hindering water infiltration, and disintegrating and eroding the soil directly. Obviously the impact of this factor on the soil depends on the number of people that pass by a single place and on the downward force they exert: a walker does not have the same effect as a mountain race. The compaction of the soil depends on many factors. For example, compaction is greater when the ground is wet. The concentration of water on tracks increases surface runoff and begins erosive processes. The erosive intensity depends on the gradient of the track and its length. Furthermore, when the path runs along the bottom of a gully or channel, the effect on the vegetation is added to the trampling effect and small landslides that contribute to the formation of gulleys (figure 2). Land formed by gullies where big trees live can cause these to be uprooted (figure 3).

Finally, the effect of people unintentionally walking close to the trunks of monumental trees like the yew is not negligible. (González de Dios 2015). When very frequent, it removes the leaf litter under the tree's crown and compacts the soil surface. The decomposition of leaf litter constitutes the main channel for soil to regain its nutrients, as, once mineralised by fungi and bacteria, it can once again be used by the tree. The elimination of this layer, therefore, diminishes the nutrients available for the tree. In addition, the leaf litter layer constitutes a kind of cushion that softens the impact of raindrops and reduces soil erosion, while also reducing the evaporation of the water from the soil.

Figure 1. Profile of the soil showing the surface layer containing the finest roots, and the more stony subsurface layer, where there are thicker roots. Photo: Pere Casals.

Figure 2. A path formed by erosion and the beginning of a gulley. Note the stony layer revealed by the erosion of finer matter and the appearance of roots on the path. Photo: Joan Llovet.

Figure 3. Root exposure. Vicenç Barbé Refuge (Montserrat Mountains). Photo: Joan Llovet.

4.6 4.6. Variability and genetic isolation

Scant traces of pollen suggest an ongoing, strong decline in the distribution of the yew (Mayol et al. 2015), which probably began 100-300,000 years ago and has continued until today (Burgarella et al. 2012). Glaciations would have restricted the Iberian yew populations to the more mountainous areas (Carrión 2002). Orographic complexity and prolonged isolation would have led to their genetic differentiation into small populations, especially in mountain ranges (Petit et al. 2005, Dubreuil et al. 2010, Schirone et al. 2010), such as the Catalan coastal mountains, with migrations in altitudes based on the climate fluctuations of each period (Magri et al. 2006).

The drawn out regression and fragmentation of yew populations would have initially been caused by climate factors and competition with other tree species, subsequently combined with the long history of anthropic influence on forests in the last 6,000-4,000 years, through systematic felling and intensive grazing (Thomas & Polwart 2003, Dhar et al. 2007, Piovesan et al. 2009, Ruprecht et al. 2010). The populations in the Mediterranean mountains and in particular the Prelitoral Catalan mountains –it would not be the case in the Pyrenean and Cantabrian ranges– show an extraordinary degree of genetic differentiation over short distances. In Montseny, for example, three genetically differentiated groups have been distinguished for the four populations analysed, with a maximum distance of around 10 km (González-Martínez et al. 2010).The isolation pattern associated with the distance seems to indicate a stronger genetic flow in the distant past. The intense forest exploitation that Montseny was subject to after the 15th century through to the mid-20th century, would explain the strong population fragmentation (Dubreuil et al. 2010).

These results suggest that the yew's capacity for genetic dispersal is fairly limited. Despite their high potential for propagation (seed dispersal by birds and wind pollination), yew populations show strong kinship and inbreeding, on a spatial scale of 50-100 m (Chybicki et al. 2011), to the extent that some extremely isolated populations, like those in the Azores, could be in imminent danger of extinction (Schirone et al. 2010). It may be that the fragmentation into very small stands (for example, 2.5 ha on average in Catalonia), attracts fewer seed-dispersing birds (Dubreuil et al. 2010). The genetic panorama of the yew contrasts with other trees from temperate latitudes, generally characterised by a high level of genetic diversity within populations and low differentiation in nuclear molecular markers, a genetic pattern interpreted as a consequence of large population sizes and extensive gene flow (Petit et al. 2005).

In conclusion, the genetic fragmentation of yew populations demonstrates the vulnerability of Catalan populations, which is even greater in a context of adaptation to climate change. It has also been suggested that the high genetic differentiation across short geographical distances may not be so negative, if at least some of the populations display genetic particularities suitable for survival in the new climate conditions (Linares 2013). It is debatable whether, for long-term conservation purposes, it would be beneficial to intervene to reduce the genetic impoverishment of the contingent of individuals. For example, populations could be boosted with seedlings from other areas with apparently greater genetic variability, but which are close enough to maintain the genetic particularities of the subpopulation, which could offer adaptive advantages. Addressing such a complex issue from a scientific and technical standpoint was considered beyond the capabilities of the Life TAXUS project. Decision-making, therefore, is aimed at actions which help to increase recruitment using reproductive forest material from the same populations or neighbouring populations within the same local biogeographic origin. At the same time, conservation work undertaken using silvicultural methods, may contribute to improving the gene flow within a single subpopulation as a consequence of opening the tree canopy to the light and thereby increasing the production of pollen and fruits. And this is even more the case when these actions are undertaken extensively on a local level, and not just focused on the more dense, small nuclei of populations, but also on groups of adult individuals that are more spread out, which can act as genetic connectors at a metapopulation scale, as has been experienced in the Bosc de Poblet and Serra de Llaberia, in the Prelitoral Catalonian Ranges.

The frequency of migration and propagule dispersal will be what determines whether or not a stand constitutes an isolated population or forms part of a metapopulation. Genetic exchange is seen to be favoured by the uncovered and elevated position of large female trees. Their seeds have a greater likelihood of passing mountain passes into neighbouring valleys and thereby shorten distances between populations. The greater size and height of big mother trees increases their exposure to pollen coming from different populations, which means their seeds could be expected to have greater genetic diversity than those of females in more hidden sites (Fernández et al. 2015).

4.7. Problems arising from public use

Discussion has always arisen among managers of natural spaces over the volumes of visitors that should be allowed in specific areas. The fragile balance of vulnerable habitats, combined with the eagerness of managers to raise awareness about the natural value of the land, is a complex situation to address. Raising awareness and allowing visitor's access, while regulating volumes so as not to compromise conservation aims, is a goal all managers of natural spaces should aspire to achieving.

Yew groves have an undeniable power to attract visitors, and are consequently often promoted by local tourist boards or natural space management teams. As a result, instead of being the focus of work to maintain this resource (the yew grove), some of the largest yew groves or monumental Iberian yews may be at risk of becoming mini theme parks overrun with signs, viewing points, parking, visitor centres, exhibitions and vast amounts of information. The end result is that the environment visitors find themselves in is actually more akin to an urban setting than a rural or natural one (adapted from González 2015).

Both the available information, supported by web-based resources, and the volume of activities carried out in natural spaces have increased in recent years. Visitors, who, decades ago, would not have had access to certain areas, today can easily orientate themselves thanks to web-based resources and GPS. This is a crucial factor for yew groves, which, until now, have been hidden from the wider public, both because of the physical difficulty in accessing the areas and the lack of knowledge regarding their location.

Furthermore, although education in the environment should play a major role, it cannot be the only hope for resolving the problems caused by excessive frequentation or an influx of disrespectful visitors. There is still a long way to go before all visitors are aware of the potential fragility of a woodland habitat such as the yew grove. While it may be easy to transmit the vulnerability of other habitats (eg. marshes, grasslands or wetlands), in a woodland environment this is a more complex task. Greater emphasis should therefore be placed on the need to change general attitudes: we do not need to promote the country's best hidden yew groves to rouse our emotions and enjoy nature.

Among the problems caused by excessive public use in yew groves are:

- Soil compaction, which limits the oxygen supply for roots and leads to the formation of a surface crust, reducing water infiltration.
- Decreased regeneration due to visitor trampling or deliberate removal of seedlings and trees.
- Different effects on roots, trunks and branches. Shortening or breaking of branches, etc.
- Poorly designed interventions to enable public use, hindering the normal development of trees, pruning, etc.

High visitor numbers, therefore, if poorly managed, can cause serious problems if suitable action is not taken in time. Yew groves are often located on private farmland, a long way from where the farm is managed, and have been growing alone and unheeded. A public bodies or tourist establishments often encouraging people to visit these yew groves, thereby increasing frequentation, may be seen as bothersome or undesirable by the owner. This, in turn, may generate a sense of ill-ease making it more difficult to come to conservation agreements. This is why, any dissemination of the natural values of their land, should first be agreed upon with the owner and, if an agreement is reached to promote the land, an assessment of the potential visitor capacity should be performed, both for the sake of the ecosystem and the peace of mind for those living there.

Figure 1. Yew grove that is extremely sensitive to erosive processes in a mountain ravine of the Mediterranean Region. The image on the right shows the bare soil, arising from human frequentation and a lack of a clearly defined path. Life TAXUS has worked with space managers to condition a path using faggots made from debris left over from thinning work and incorporate trail signposting. Photos: Jordi Camprodon.

4.8. Issues related to climate change

The climate in Europe is changing due to global warming, and differences in regional climates are set to increase. Southern Europe is where the worse conditions are predicted (high temperatures and drought), where forest fires are expected to increase. The north and east will be less affected by drought in the long term, but they may suffer regular flooding and temperature increases with periods of water shortages.

Changes in the distribution of a species with such longevity as the yew are not easy to predict. The yew and its habitat are already showing signs of decline in south-eastern Europe caused by different factors (Thomas & Polwart 2003). Climate change will probably exacerbate the situation in the Mediterranean region, either directly or through its by-products, such as the increased risks of forest fires or erosion.

It is predicted that the aridity associated with climate change will increase competition for soil water between the yew and other woodland species such as oaks or pines, and will favour the spread of plant diseases (Loarie et al 2009, Thomas & Garcia-Martí 2015). Old individuals will certainly decay progressively over the coming centuries thanks to the lack of water availability. In the more humid northern zones, the yew will find better climate conditions, but it will be slow to occupy new areas due to competition during the regeneration process (Thomas & Garcia-Martí 2015).

It is likely that from the middle of this century, Catalan yews will suffer a strong decline (Burgarella et al. 2012, Àguila et al. 2015), as shown by the modelling of Catalan yew groves' potential future habitat (figure 1). Yew populations will tend to move northwards, in so far as is possible, where changes in climate conditions will better suit their ecological requirements.

Those populations that have a low dispersal capacity or which are topographically isolated in southerly mountain ranges may eventually disappear by the end of the 21st century (Àguila et al. 2015). More northerly yews will be able to maintain their ecological profile relatively unharmed, with the exception of low-altitude populations, which will have to move to higher areas. Other studies, such as those conducted on yew groves in Portugal, reveal the same results (Draper & Marques 2007).

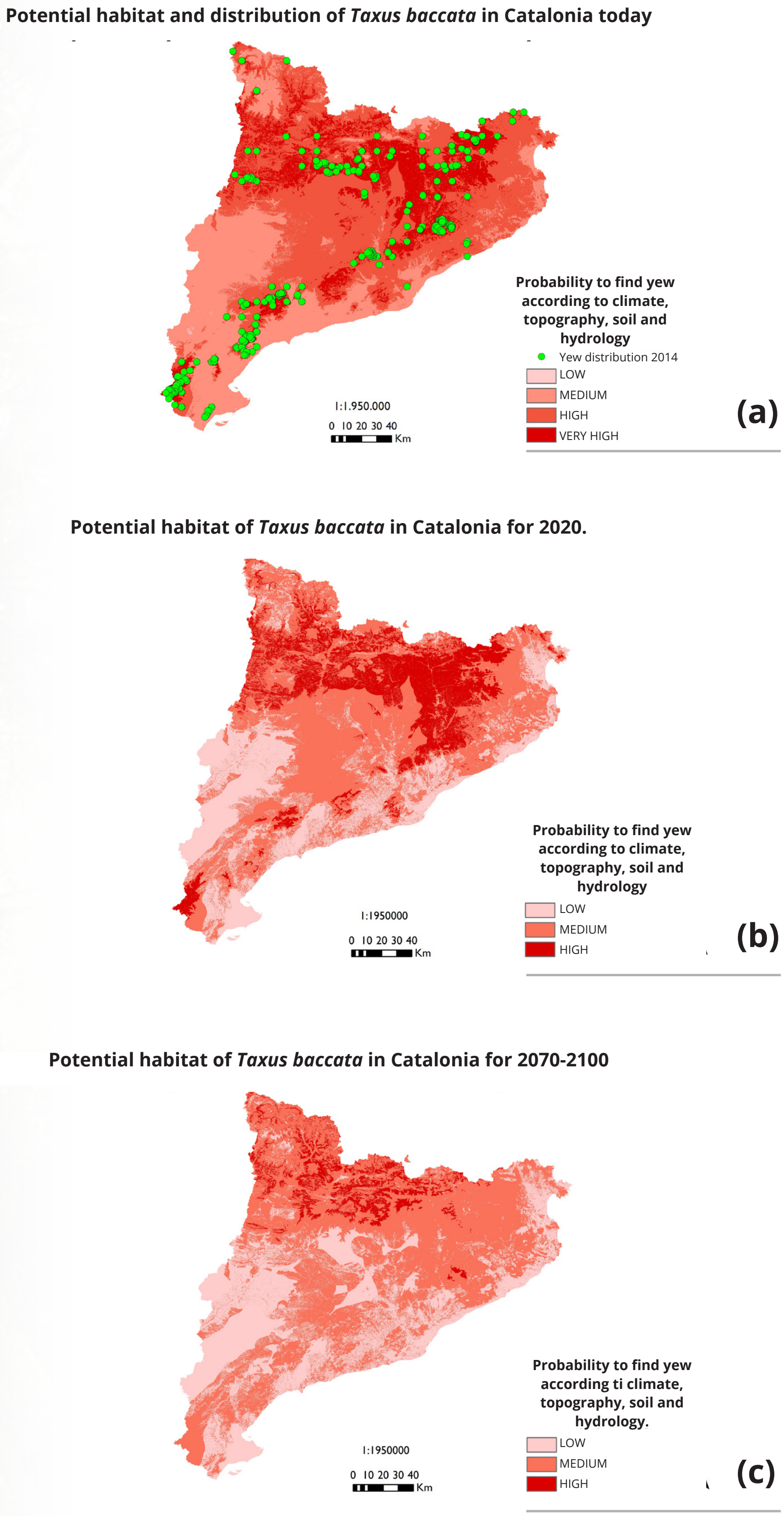


Figure 1. Potential habitat and distribution of *Taxus baccata* in Catalonia today (a) and predicted for 2020 (b) and the period 2070-2100 (c), according to Àguila et al. 2015.

5. CONSERVATION ACTIONS

5.1. Land stewardship agreements. Management and conservation of the habitat through social involvement

1. Description

Land stewardship is a strategy for involving institutions and landowners and land users in the management and conservation of nature and the countryside. Within the framework of this project, voluntary agreements are set up between landowners and land stewardship organisations with the aim of directly managing or supporting the management of habitats of Community interest, in order to maintain or restore their value.

These agreements are especially useful in areas of great natural value, which require a combination of management and conservation.

2. Aim

The main aim is to gain the collaboration of the landowner so as to undertake management and conservation actions in habitats on their land, clearly defining the specific aims and duration of the agreement. Through the different land stewardship options and instruments, a tailormade agreement can be reached between the landowner and management body, which has different levels of legal certainty, and is therefore adaptable to different situations: productive farms, absentee landowners, geographical contexts, etc.

3. Introduction to land stewardship

In the framework of the LANDLIFE project, developed by the Land Stewardship Network (XCT), a very simple guide to land stewardship has been produced to promote land stewardship as a tool for involving society in the management of natural heritage in Europe (available at the project's website http://www.landstewardship.eu).

Also available (in Catalan) is a guide to land stewardship agreements and opportunities aimed specifically at promoting this instrument for private landowners (http://www.xct.cat/mm/file/2015/2015_Opcions_x_custodia_territori_Guia_Acords.pdf).

4. Proposed action

When the land stewardship organisation detects an action area, first the landowner must be located. The most direct way to find out who owns an area of land is to request a simple note from the Land Registry (this document is useful for signing the future agreement). Sometimes this information on the land is not available in the registry, in which case there are various options for identifying the owner, and partners are often necessary for this. In Life TAXUS we have used two: the municipal town council and the General Forest Management department of the Catalan Regional Government.

The process for arriving at a signed stewardship agreement can be very lengthy, although this is not always the case. This process identifies the interested parties in relation to the land and requires these parties to understand and respect one another, in order to later reach a shared vision on how to manage the land. The agreements are based on mutual trust, and in all cases the landowner (whether private or a town council) must feel comfortable and happy with the agreement's implementation.

The basic content of a land stewardship agreement is as follows:

- Presentation of the involved parties.
- Area to which the agreement applies: the whole property or just a part, identifying the land areas.
- Description of the values and items of interest that justify the agreement.
- General and specific aims of the agreement.
- Commitments (or actions) of the environmental organisation and landowner.
- Management recommendations, to be later incorporated into the management plan.
- Access to the property, communications and awareness raising.
- Expenses arising from the agreement and parties responsible for meeting these.
- Duration of the agreement. Any monitoring laid out in the agreement to be carried out by the organisation. A yearly visit to the site is recommended as a minimum.
- Other aspects, such as measures to be taken should ownership be transferred or the fee to be paid to establish an in rem right for the direct management of the land.

There are different land stewardship options and instruments. The following figure shows a summary of the different options. You can find more information in the aforementioned land stewardship guide.

Most often, a contract is drawn up between the two parties of their own free will in which the owner maintains management of the land but the stewardship organisation participates in the management plan and provides the owner with support and advice.

Figure 1. Options and land stewardship instruments. Source: Sabaté et al. 2013.

Monitoring stewardship agreements is key to ensuring their compliance and meeting the long term conservation aims of the habitat. The owner is always informed of all developments and the extent to which the agreement aims are being achieved thanks to the monitoring carried out by the stewardship organisation. The results of the monitoring can be found in annual reports provided by the land stewardship organisation to the landowner.
Today, the XCT is working to create an official register of stewardship agreements and on a manual for the design and implementation of stewardship initiatives through best practices. More information can be found at:
http://www.xct.cat/ca/cdr/5_documentacio_gestio_entitats_custodia_territori.html

The Life TAXUS project has signed up to 59 agreements with private owners in Alta Garrotxa, Ribera Salada, Montserrat, Serra de Prades, Serra de Llaberia and Serra de Cardó for the conservation of yew groves. It has developed three tools with greater or lesser legal certainty:

- Authorisation of the owner to carry out works.
- Land stewardship agreement to provide land management support.
- Constitution of in rem rights for transferring land ownership. Applied in the case of the Serra de Llaberia Consortium, which had directly managing certain yew groves for 25 years.

In the case of Serra de Llaberia, the agreement most often includes a management plan. It was decided that the plan would take the format of a Technical Plan for Forest Improvement and Management which can lead to tax benefits and property transfer cost reductions. In addition this kind of plan can open access to grants for sustainable forest management, offered by the Catalan Regional Government for improving Catalan forests.

5.2. Silvicultural treatments to regulate competition

1. Description

The removal of a portion of competing species enables yews to develop which would otherwise not survive or would subsist as part of the dominated understory layer, losing apical dominance and growing side branches in search of light. Actions to regulate the competition to yews focus on diameter and height growth, flowering and fruiting, and recruitment capacity.

2. Aim

Yew growth and regeneration is significantly improved through silvicultural treatments applied to the competition (Caritat & Bas 2007, Ruprecht et al. 2009, Camprodon et al. 2015). The fruit production of yews and other accompanying species eaten by the fauna can also be improved following a reduction in light competition (Camprodon et al. 2015).

The aim, therefore, is to improve yew vitality and recruitment capacity by reducing competition from other species. These actions must also lessen the susceptibility of the yew to fungal attacks, reduce the risk of forest fires and increase their adaptation and resilience to climate change.

The same actions can be applied to other local species that are of interest or typical to the area: *Ilex aquifolium, Tilia platyphyllos, Sorbus aria, S. domestica, S. torminalis, Crataegus monogyna, Phillyrea latifolia, etc.*

3. Proposed action

3.1. Treatment types

The methods to be used are selective thinning (heavy or soft), pruning large tree branches and removing allochthonous woody species. These actions imply marking each tree to design tailormade silvicultural actions, depending on the competition types and woodland structure. .

Treatment 1. Soft thinning. Aimed at reducing the basal area in a radius of 5 m from the yew, but avoiding opening the canopy to excess (figure 1).

To reduce competition the treatment priorities should be as follows: 1) apical, mechanical and light competition in juvenile and adult yews, 2) lateral mechanical competition, 3) water competition, often already included in the aforementioned treatments.

The tree cover density before/after treatments was 70.5 to 56% in the Alta Garrotxa (a 19.5% reduction) and 66 to 51% in Llaberia (a 15% reduction). Direct light exposure rose from 39 to 51% in the Garrotxa and from 36.5 to 53% in Llaberia.

An average 40% reduction in the number of competing trees is proposed (or in canopy cover). This reduction is set at between 45% in the densest stands and 25% in stands that are more open.

Treatment 2. Heavy selective thinning. Aimed at reducing canopy cover in a radius around the target yew(s) of up to around 10-12 m from the target yew. Reduction in lateral light competition is prioritised based on the light the yew can receive, in other words the light blocked by trees depending on the orientation of the sun's rays. This is applied first to female adults in the dominant layer (as a guideline, with a diameter class of at least 10 cm). The reduction in cover was similar to that of the soft thinning, but with a greater increase in direct incident light (from 36.5 to 61%). No more than 35-40% of the basal area is extracted, so as not to open the canopy in excess.

In all thinning work, care must be taken not to expose the yew to excessive light entry (Perrin & Mitchell 2013). Because of its shade-tolerant temperament, especially in the Mediterranean region, care should be taken not to shock individual trees by sudden exposure to light. Hence, a two-phase measure could be taken, which enables the tree's progressive adaptation to the increase in light. In an initial year, soft thinning is carried out (for example reducing the canopy cover density by between 20-60%); the behaviour of the yew is monitored during the following growing season and if no adverse reaction is observed, once dormancy has begun, a second thinning is carried out. For the yew treated by Life TAXUS, the percentage of affected leaves (yellowing or fallen from the tree) was measured. There were significant differences between control yews and those where heavy thinning was performed, but with a minimal effect on the crown (an average of 11% of its volume). The soft thinning produced insignificant changes; less than for the control yews, probably because the reduction in competition has reduced stress in a year (2016) particularly affected by summer drought.

Treatment 3. Pruning. Medium to high pruning (from 2 to 5 m) of the live branches that interfere (or could do so in a future) in apical growth or intercept the light. Even high pruning could be applied for large yews.

Treatment 4. Removal of woody alien species. Invasive species are prioritised, such as black locust. This is understood as an improvement to the habitat regardless of whether or not the alien species competes directly with yew trees. Next, glyphosate is injected, in the concentration indicated by the manufacturer, into perforations at the base of the trunk. Various perforations are made at an angle of 45 degrees, in amounts that are proportionate to the diameter of the trunk. The tree is not felled until it is completely dead.

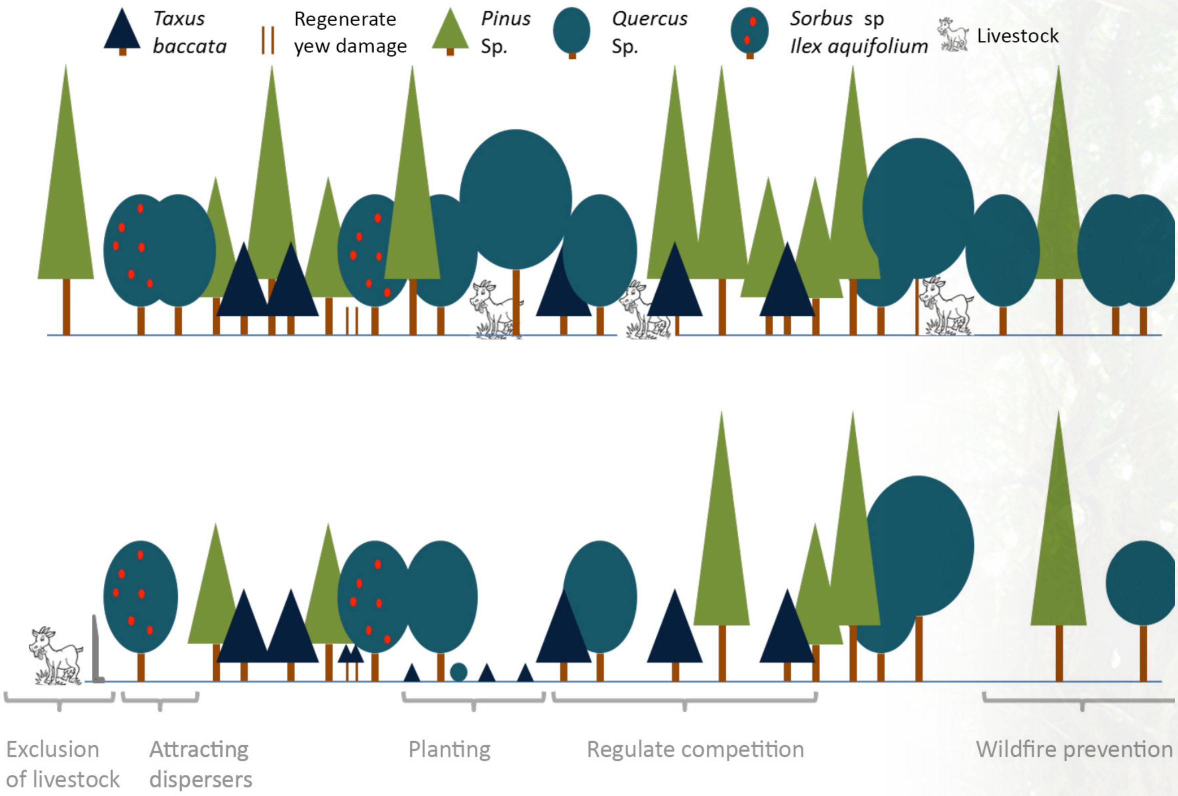


Figure 1. Diagram of thinning carried out in a yew grove. Original: Jarkov Reverté.

3.2. Treatments recommended based on woodland type

Adapted from Caritat et al. 2015, see chapter 3.2 for details of the forest structure.

Type 1. Dense yew grove. Yews can become dense to the extent that their density can impede their regeneration and that of other species. Soft thinning of yew individuals or other species in the dominant layer can help. Actions focused mainly on promoting heavily covered mother trees, to stimulate fruit growth, veteran individuals of great heritage value, typical and scant accompanying species and groups of regenerated yew. In highly dense adult stands of the same age class, experiments can be carried out opening small clearings to promote regeneration.

Type 2. Mixed forest of yew with conifers and broadleaf trees. The competition for light and water is intense in high-density woodlands from young or medium-aged yew, holly and whitebeam. Actions would focus mainly on promoting heavily covered trees of all ages through soft and heavy thinning. For large dominant pines, girdling can be applied, especially if there is regeneration that can be affected by falling trees (see breakdown) or high pruning.

Type 3. Mature yew grove. Very mature yews often suffer from mechanical and lateral light competition. Soft thinning or high pruning is recommended on often large competing trees.

Type 4. Holm oak forest with yew. Mechanical competition for light and water is often stronger the denser the forest. Heavy or soft thinning of holm oaks and other accompanying broadleaves and conifers that compete with the yew and typical species. Medium or high pruning of large hardwoods, especially when of an exceptional or rare size within the woodland (*Quercus, Acer, Tilia, Fraxinus, Prunus*, etc.). Preserve rare broadleaf trees, even if they may be competing with yew, if they are larger or have a greater chance of growth.

Type 5. Beech forest with yew. Yew and holly often grow in groups in clearings or under the beech cover. They can be promoted by way of soft thinning or high pruning of competing beeches. For some dominant straight beech trees, girdling can be applied, especially if there is regeneration that can be affected by falling trees (see breakdown).

Type 6. Pine forest with yew. Standard adult conifers tend to grow in a dominant layer, well above the height of the tallest yews, thereby reducing mechanical and light competition on yews, which is limited to the lower branches of the pine crowns. Soft thinning is often enough, except for stands with a high density of pines. For large dominant pine, girdling can be applied, especially if there is regeneration that could be affected by falling trees (see breakdown) or high pruning.

Type 7. Formations where the yew forms part of the understory or forms a subordinate tree layer. Juveniles may be well protected by the tree canopy, waiting for neighbouring trees to die, and thereby giving them the chance to grow. If this does not happen, they often end up covered by mechanical competition and do not fruit due to a lack of light. Thinning of neighbouring trees (often a single individual) that come into contact with the crown or the roots of the juvenile or dominant adult yew. Trees that will impede the future apical growth of subordinate yews can be felled or pruned.

Figure 2. Treatment process for regulating yew competition: a) plot before treatment; b) marking trees to be felled or pruned and inventory of initial state; c) performing the thinning; d) ecological monitoring with the target yew in the centre. Serra de Llaberia. Photo. Jordi Bas.

Tree girdling

Girdling is the complete removal of an approximately 10 cm strip of bark and outer wood of a tree. This cuts the circulation of phloem and cambium, the tissue that regenerates the secondary growth of the girth, thereby weakening the tree and eventually killing it if it cannot regrow from below the ring.

The aim is to reduce competition without having to remove the tree (for example where extraction is complicated or there is a large amount of regeneration on the site...), and to favour biodiversity. The ringed tree will decay over the years and can be colonised by fungi and saproxylic invertebrates and will be the perfect substrate for woodpeckers to excavate their nest holes in. As the bark peels away from the tree it offers shelter for bats. To favour their occupation by woodpeckers, it is preferable to girdle trees that are straight and have large diameters (from around 20 cm in diameter and a trunk height of at least 4 m).

With a saw or axe, two cuts are made between 10 and 20 cm from each other and up to 2 cm deep, and the space between is removed.

Figure 3. Tree girdling process. This can be done with a chainsaw or axe. Photos: Jordi Bas.

Some results

Life TAXUS has reduced competition in 186 ha for more than 8,000 yews and has intervened in more than 20,000 trees (an average of 2.7 trees per yew) including mainly holm oak, downy oak, Portuguese oak, Italian maple, field maple, Aleppo pine, black pine and Scots pine.

The average size of yews in Llaberia mountains was 8.1 cm (+- 4.8) in diameter in soft thinning and 10.8 cm (+- 6.0) in heavy thinning. In the Alta Garrotxa mountains the average diameters were 12 cm (+-7.3). The maximum diameters of treated yews were 31 cm in Llaberia and 59.5 cm in the Garrotxa.

During the first year following treatment, significant growth was observed in height and more moderate growth in girth in treated yews compared with control trees (figures 2 and 3). The impact of exposing the yew foliage to light was minimum.

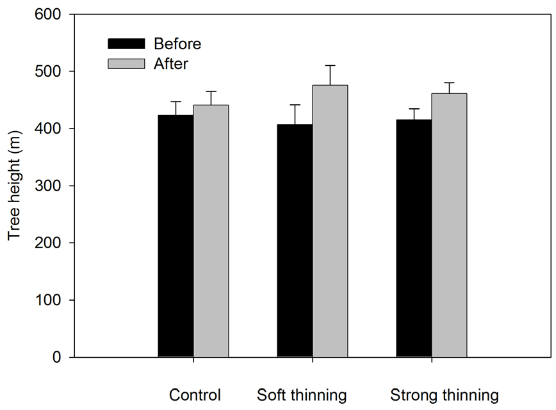


Figure 4. Net growth in height based on the site and treatment.

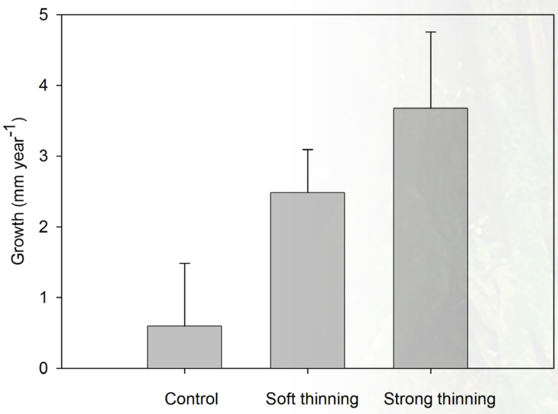


Figure 5. Diameter growth per year and based on treatment.

4. Contributing factors

4.1. Accompanying tree species

Tree species of interest are preserved like holly, maple, linden, cherry and whitebeam, etc. However, in certain circumstances trees can be felled or shoots removed or these trees can be heavily pruned, if they are competing with yews or other species considered to be of greater value. If they are protected species, the corresponding authorisation must be given. Large and old oak and other broadleaf trees, which can sometimes be found scattered throughout the stand, should be left standing.

4.2. Residue from forestry work and dead wood

Residue from forestry work can be extracted or scattered depending on each case. If extracting, the trunks should be piled up in long segments (2-3 metres) and the branches shredded on the track. Particular care should be taken not to disperse robinia seeds or those of other alien species. Logging residue that is less than 25 metres from a forest track is removed or shredded, according to existing regulations.

With regard to leaving residue on site, branches can be scattered and shredded, without covering more than 50% of the ground surface area. If considered suitable, they can be made into small piles, which can serve as refuge for fauna when understory clearing is being carried out. Trunks should only be cut into large pieces, if it is convenient to pile them up on the ground. They should not be left in piles by tree stumps, but preferably left in piles supported by a rock or laid out following the contours of the land in order to provide protection from erosion.

It is recommended to consider the generation of dead wood to favour biodiversity and forest dynamics. Leaving medium-size (15-30) or large (more than 30 cm in diameter) trunks is considered to be very positive for the saproxylic community (especially fungi and beetles). Likewise, leaving high stumps or girdled trees (standing dead wood) is also of value. As a guideline, leaving a density of between 5 and 30 dead trees per ha is optimum, but the stand should not be forced and actions should be modified according to the woodland dynamics.

Regarding the high stumps, around 20 stumps/ha should be left at a height of 40 cm, thereby particularly favouring saproxylic fungi and beetles.

4.3. Selective undergrowth clearing

Selective undergrowth clearing is carried out to prevent fires (see chapter 6.9). Aside from this aim, it should only be carried out to reduce competition or facilitate extraction. No more than 40% of shrubs and lianas should be removed to preserve biodiversity (Camprodon and Brotons, 2006).

It is recommended not to extract the ivies often found on yews, except those that are significantly affecting the crown, especially in veteran yews.

4.4. Herbivore grazing and exclusion

During extraction, care should be taken not to damage livestock exclusion fences. They can be removed temporarily to undertake the work. The land's subsequent use for moderate grazing can be beneficial in reducing the vulnerability of tree crowns to forest fires.

4.5. Trees with nests and cavities

Take care not to select trees for felling that have cavities, bird nests or that serve as refuges for mammals. In particular, leave trees with woodpecker cavities, especially those with multiple cavities, regardless of whether the trees are alive or dead. Preserve all trees with nesting platforms for raptors. Large pines with high bifurcations are known to form cavities for bats.

4.6. Threatened flora and fauna

When carrying out interventions that imply a modification to the current stand structure or its access routes, threatened or singular flora and fauna should be taken into account to ensure their conservation in the area in accordance with existing legislation.

4.7. Operators

Performing improvements to yew forest habitats following all the above mentioned criteria requires expert operators. These professionals have to be capable of carrying out complex manoeuvres to determine the direction of fall. The team leader should participate in marking the trees as this person can help make the right decisions and ensure that all criteria are followed by the rest of the team.

4.8. Selling the wood

The productive use of the resulting wood may be considered depending on the quality of the site, profitability of the woodland, access conditions and sales possibilities. It may represent an alternative if there is a shortage in funding for carrying out habitat conservation works.

5. Monitoring indicators

Two kinds of monitoring have been defined: for populations and for individuals.

5.1. Monitoring the demographic structure of the population

A population is considered that which is formed by trees that are no more than 500 m apart, which is the maximum distance for wind-carried pollen (Serra 2009). For demographic monitoring, each population is delineated, obtaining the real occupied surface area by habitat type. The population can then be demographically classified. Each individual is georeferenced and numbered to allow the population to be identified over the course of time. The optimum time for locating populations is winter or early spring because the lack of foliage of most accompanying trees and shrubs makes it easier to spot the yews. For each individual, the state of development, sex, height and diameter are recorded. This provides the age classes for each population and allows us to deduce whether it is an aging population or one with generational replacement (Andrés et al. 2007, Sanz et al. 2007, Schwendtner et al. 2007).

State of conservation (Serra 2009):
• Favourable: regular distribution of sexes and ages, with both seedlings and juveniles and adults, population of at least 50 trees.
• Unfavourable-inadequate: irregular distribution of sexes (few females), under-recruitment (less than 10% of trees with diameter of <5 cm) or population of between 10 and 50 trees.
• Unfavourable-poor: inexistence of females, zero recruitment (all trees with a diameter of> 20 cm) or population with fewer than 10 trees.

5.2. Monitoring individuals receiving treatment

Measurements are taken from a circular site with the individual to be measured taken as the centre. The recommended radii are 3 m for juveniles and 5 m for adult yews. They are measured before and after treatment and in control sites (without treatment). It should be done after the growing season, in the summer, before broadleaf trees begin to lose their leaves. The fruits should be counted in October.

1. Identify the individual with a plaque if possible at a height of >1.5 m and georeference it. Specify the treatment type applied or if it is from the control group.
2. State of development: seedling (up to a height of 1.3 m), juvenile (height of 1.3 m up to 2.5 cm diameter), adult (from 2.5 cm diameter). This classification is arbitrary for making it easier to take the sample.
3. Sex: male, female, male/female, undetermined.
4. Diameter of yew crown at the two perpendicular axes.
5. Diameter at breast height (DBH). At 1.30 cm from the base, always from south of the trunk. The measuring point should be marked with white string or a dendrometer for trees measuring >5 cm DBH.
6. Height growth. Measured with an extendable pole that reaches the tree's apical area.
7. Side growth. Take 3 leaf growth measurements. Measure the growth for this year since the autumn bud. Mark the start point of the previous year with string.
8. Tree canopy measured using hemispherical photography. Camera with fisheye from the apex of the yew. Always ensure the camera is straight and that the top part of the photo in the screen is looking northwards (you should use a compass and spirit level). Analyse the photos using the GLA, Gap Light Analyser programme (Canham 1988).
9. Isotopic relationship 13C:12C (δ13C). This has been used to investigate relative efficiency in water use (Donovan & Ehleringer 1994, Lloret et al. 2004) and can be used as an indicator of the plant's water stress. Take 3 samples of thin branches from the top of the crown, from which 30 leaves from the previous year are later separated in the laboratory.
10. Browsing pressure: apical bud touched, side branches with signs of being eaten, dry branches or apical trunk or apical trunk and/or side branches broken and dead.
11. State of health. Assessed as the percentage of crown with yellowing leaves. Record any fungal affectation, especially from *Armillaria*, parasites, etc. Vital state: good, affected, very affected, in decay or dead.
12. Cover of plants that affect the yew on two levels: a) that touch it and b) that cover it vertically.
13. For each woody individual, record the species, the diameter, the number of shoots, whether it has ivy and if it has been marked for felling.
14. Regeneration. Count yew regeneration throughout the site, as well as that of woody species.
15. Fruit: approximate quantitative estimate of the fruit that can be seen on the tree. State of conservation (Serra 2009): favourable, each fertile female produces 5,000 fruits/year; unfavourable-inadequate, between 1,000 and 5,000 fruits are produced per year by the female; unfavourable-poor, production of fewer than 1,000 fruits/year.

Figure 6. Yew with dendrometer (left) and measuring the tree canopy using hemispherical photography. Photos: Jordi Bas.

5.3. Silvicultural treatments to regulate the understory

1. Description

In general, in Mediterranean yew groves there is relatively little regeneration due to high tree density creating an excess of shade, a lack of flowering and fruiting and high competition. In addition, herbivory by domestic ruminants can cause very serious damage to seedlings and juveniles.

It should be kept in mind that while the understory provides protection against herbivores, it also competes with seedlings (h<1.3m) and juveniles (h>1,3 m and DHB<2.5 cm). Yew seedlings often grow protected by the underbrush, such as Spanish sarsaparrilla and bramble bushes, which provide protection in two ways. Firstly, they make it difficult for herbivores to enter and move around; and secondly, and more importantly, they reduce solar radiation, and in turn lower direct evaporation of soil water and foliar evapotranspiration in small seedlings, allowing for better water availability during the summer months (Fernández et al. 2015). Seedlings grow well under the canopy, as they are sciophilous. However, it should be ensured that shrub cover does not hinder growth through mechanical and water competition.

2. Aim

To improve yew regeneration, its survival and growth in both low and high density stands and, especially, in connecting areas. To leave a strip of understory to provide protection against herbivores (thorny species such as Spanish sarsaparrilla, brambles, junipers, etc.) and at the same time carry out thinning of the tree and shrub layers.

3. Proposed action

Shrubs and lianas (brambles, Spanish sarsaparrilla normally) should be removed which are climbing up the crowns of juvenile yews and can hinder their growth. In some cases, a small strip, a metre in radius, can be opened around any regeneration. However, great care must be taken and interventions should only be carried out in cases where problems with the vital status of the yew have been observed, as the protection that the shrub strip provides against herbivores should not be affected.

A high presence of Spanish sarsaparrilla or brambles climbing adult yews should be removed, especially in clearings and on woodland borders, where more light can penetrate. Ivy should not be cut down because of its importance as a refuge and food for fauna, except for cases where thick ivy may severely affect yew growth.

Figure 1. Yew seedlings growing among brambles. Despite its slim appearance, apical growth is not interrupted no action need be taken. Serra de Llaberia. Photo: Jordi Camprodon.

Figure 2. Yew juvenile covered by the understory and remains of branches, which protects it from herbivores, but at the same time represents fierce competition. For the moment it has been able to grow shoots that go above the vegetation, but their scarcity may hinder the yew's growth and have a negative effect on its shape as an adult tree. In this case it would be better to remove excess cover. Serra de Llaberia. Photo: Jordi Camprodon

4. Contributing factors

The work of selective undergrowth clearing should be done with great care to avoid affecting the regeneration of yews or other species.

Widespread selective undergrowth clearing should only be carried out to prevent fire (see conservation actions 5.9). In other cases, it should only be applied to reduce competition or facilitate extraction. No more than 40% of shrub and lianas vegetation should be removed in order to preserve biodiversity (Camprodon & Brotons 2006). Before carrying out underbrush clearing, ensure there are no yew seedlings in the thickets, even if there is an absence of adult individuals. These should then be marked and, if possible, protected.

If residue is left on site, branches should be scattered and shredded, covering no more than 50% of the ground surface. If considered appropriate they can be made into small piles, which can serve as refuge for fauna after the underbrush has been cleared.

In some areas, work cannot be done between the months of April and July (inclusive) due to restrictions concerning the breeding of protected species. A work plan should therefore be agreed upon with the forest management for the different action areas.

5. Monitoring indicators

Two kinds of plots with two aims: 1) Circular plots for measuring recruitment success and identifying regeneration distribution patterns. The count should be done after any plant deaths during the summer.

1. Counting regeneration. Seedlings: up to 1.3 m high, juveniles: from 1.3 m to 2.5 cm in DBH.
2. Distance from seed trees, in shrub facilitators and clearings (García et al. 2000).
3. Canopy density (for example, measured with hemispherical photography).
4. Regeneration rate: percentage of seedlings and juveniles compared with adults.

2) Sites for monitoring the effect of treatment on regeneration. Measured on a selection of seedlings before and after treatment and in control plots (where no treatment has been undertaken).

Variables that serve to assess the effect of treatments (these can also be applied to sites where regeneration is to be counted):

1. Identify the individual with a metal plaque and georeference it. Specify the type of treatment applied or if it is a control specimen.
2. Height growth of the seedling or juvenile.
3. Radial growth of juveniles through the DBH and maximum diameter of the crown and its perpendicular axis.
4. Annual growth of new shoots.
5. Growth of the surrounding shrub cover.
6. State of health. Taken as the percentage of crown with yellowing leaves. Note any presence of fungus in juveniles, especially from Armillaria, parasites, etc. vital status: good, affected, very affected, in decay or dead.
7. Browsing pressure: count of the number of shoots that have been browsed.

Figura 3. Teix totalment cobert per arítjol i rebrots d'alzina. Serra de Llaberia. Foto: Jordi Camprodon.

5.4. Phytosanitary treatment

1. Description

Stress conditions, especially if caused by water deficiency, can increase the likelihood of fungal infection and even result in the death of the yew, despite it being an especially resistant species. Yew deaths have been recorded due to root damage caused by Armillaria fungus (Armillaria sp.) following several years of drought, while some partially affected trees recovered after intensive pruning (Caritat & Bas 2007). It has been detected that this is the fungus that causes most local damage to Catalan yew forests.

In affected trees, Armillaria can cause a disease that causes root rot. The main symptoms are detected in the aerial parts of the tree with wilting in the branches and eventually death. Some trees do not present visible symptoms of the disease in the crown but root damage makes them very vulnerable. Fruiting structures can often be found around the base of infected trees.

Armillaria can be detected by observing the root bark and the base of the trunk, as the disease causes strips to peel off the tree revealing clearly visible white sheets of mycelium beneath (see chapter 4.2).

In section 4.2, other diseases and plagues are also described that can be observed in woodland yews or ornamental yew trees.

2. Objective

The goal is to avoid the spread of different pathogens, especially infection through Armillaria, through the application of silvicultural treatment in yew groves. Although Armillaria and other pathogenic fungi form part of natural lifecycles in ecosystems, the presence of just a few infected yews should be treated seriously by forest management due to the low number of yew groves and the exceptional nature of their habitat.

3. 3. Proposed action

This disease caused by Armillaria is difficult to deal with as the infective structures of the fungus can be as much as a metre below ground level and are located beneath the root bark.

The main treatment against Armillaria is carried out through the continued activation of the plant's defence mechanisms with the aim of improving its physiological and environmental conditions. However, in some cases of isolated or planted trees, the fungi may be chemically removed by injecting fungicides into the affected trunk, physical barriers may be put in place in the form of approximately one-metre-deep trenches or biological methods used that employ bacteria like Pseudomonas fluorescents or antagonistic fungi like Trichoderma sp. and Gymnopilus spectabilis (http://www.avisosneiker.com/wp-content/uploads/2011/02/FICHA-armillaria_3.pdf, Mesanza et al. 2016).

Treatments of entire yew groves consist in cutting and removing the trees affected by the fungus to avoid its spread and carrying out partial pruning on adult yews to revitalise the trees and increase their resistance to the disease (Camprodon et al. 2015).

Ornamental yews affected by coccidia are sometimes treated by spraying insecticide on the branches and leaves or systemically by injecting it directly into the trunk (Crespo et al. 1987).

The treatment of the fungi Laetiporus sulphureus and Heterobasidium annosum is done by removing the fruiting structures to avoid the spread of the rot and removing the stumps of old branches or trunks that seem to be rotten (Cortés et al. 2000).

4. Monitoring indicators

Variables that serve to evaluate the effect of the treatment are:
1. Growth in tree girth, measured using a dendrometer.
2. State of health, evaluated as the crown percentage with yellowing leaves.
3. Annual growth of new shoots.

Figure 1. Armillaria mycelium sp. in the trunk of a young adult yew killed by the infection. Serra de Llaberia. Photo: Jarkov Llaberia.

Figure 2. Intensive pruning to treat trees infected by *Armillaria* sp. in the Miseclòs yew grove. Photo: Antònia Caritat.

Figure 3. Adult yews affected by *Armillaria* in the Miseclòs yew grove (Alta Garrotxa). Low branches can be observed, which are dry or have very few needles, as well as a large amount of trunk regrowth and dendrometers for monitoring growth. Photo: Jordi Camprodon.

5.5. Livestock management and protection of yew regeneration

1. Description

Although understory grazing provides undoubtable benefits for the conservation of the structure and composition of many Mediterranean plant formations and landscapes, various studies indicate that browsing on juvenile yews is one of the main causes of the collapse in yew populations (see chapter 4.3).

It is important to remember that the conservation management of yew regeneration should simultaneously take into account all the components that are included in its environmental network: bird dispersal, herbivores and potential nurse plants (García & Obeso, 2003).

2. Aim

- To evaluate the impact caused by herbivores on a yew population
- To identify the techniques to protect against herbivores

3. Actions proposed to protect regeneration

The decision-making process into how to protect regeneration must take into account yew grove structures, browsing intensity and whether or not nurse plants are present (table 3).

Table 1. Proposed actions based on the proportion of yew regeneration, nurse plant density and herbivory intensity.

Yew grove	**Habitat**	**Herbivore**	**Actions**
Regeneration/Adults	Nurse plant	Intensity	
High rate >60%	Indifferent	High >40%	Regulation of herds or wild ungulates. Exclusion fences.
		Low <40%	No action. Periodic monitoring.
Low rate <60%	High density (>40%)	High >40%	Plant under nurse plant. Regulation of herds or wild ungulates. Monitoring of regeneration.
		Low <40%	Plant under nurse plant. Monitoring of regeneration and planting.
	Low density (<40%)	High >40%	Individual guards and exclusion fences. Plant nurse plants in microhabitats and plant yews. Regulation of herds or wild ungulates.
		Low <40%	Creation of microhabitats with nurse plants and subsequent yew plantation.

The types of protection mechanisms can be grouped into two classes: natural or artificial.

3.1. Regulation of grazing by domestic or wild animals

Hunting and grazing management plans should be drawn up, outlining any livestock and silvicultural management actions to be taken, as well as measures to protect the yew, keeping in mind livestock needs, available grazing areas and the composition of understory companion plants. Some examples of collaborative actions with farmers are: agreeing on routes and rest months in yew stands, offering compensatory measures such as installing a watering point to change the animal paths or clear an area of scrubland to allow for subsequent regrowth.

3.2. Construction of fences to protect regeneration

For cattle it is relatively straightforward to install electric fences to stop animals entering areas where there is yew regeneration. For other kinds of animal, game fencing could be an option, but this is more expensive and potentially problematic for the normal functioning of the ecosystem. In this case, the fences are built with game netting, emplacing a stake every 3 or 4 metres or making use of existing trees. The fenced areas could be of different sizes, depending on if they are protecting just a few juveniles, or an entire stand with various seedlings measuring tens of square metres (30-1,000 m2). These fences can be moved to other sites as the yews grow out of reach of the goats. In any case, the location of the fencing should be discussed with the farmer and potential problems analysed together (figures 2 and 3).

3.3. Individual guards

Individual tree guards provide protection against herbivores (figure 4) and can also protect from sunlight through the use of shade nets (advisable only in the first years of growth). These can be purchased from different retailers or can be built onsite with metal mesh and bars.

3.4. Creation of microhabitats using nurse plants

Maintaining nurse species in the shrub layer may favour the development of yew seedlings (Schwendtner et al. 2007, Farris et Filigheddu 2008). First it should be ascertained what effect ungulates may have on these plants (see chapter 4.3). To this end, it is recommended to observe the extent of browsing on the species in the stand. The animal species is key: goats consume a higher proportion of lignin that sheep and therefore prefer woody species, like holly or gorse. If yew germination is very low and frequency of herbivores moderate to high, it is recommended to plant yews beneath nurse plants.

4. Herbivore impact assessment

There are numerous methods to estimate herbivore impact on the ecosystem based on the animal types, the affected component or process and the available budget (See the information provided in *Forest Ecology and Management*, volume 120, year 1999).

In the case of the yew, there are specific studies (Linares 2013, García et al. 2000, García & Obeso 2003, García et al. 2000) in which the woodland structure is also considered to be a key element. These studies have demonstrated that the presence of **nurse plants** consisting of fleshy-fruited shrubs (FFS) have a protective role in the regeneration of the more southerly yews in Europe and, at the same time, attract the yew's seed-dispersers, which is a highly beneficial association for the seedling and juvenile stages of the yew.

Nurse plant: beneficient plant that helps other plants by creating a more suitable physical environment beneath its canopy (Linares 2013). This also takes place indirectly in the case of the yew, as a third element comes into play: dispersers (when frugivores are attracted by the shrubs and disperse the seeds of the associated tree species) and herbivores (when the shrubs provide protection for the trees' propagules against herbivores) (Farris & Filigheddu 2008).

Herbivore impact assessment, therefore, should take into account both the structure of the habitat of the yew population and its populational structure, and the more direct herbivore parameters (herbivory presence, herbivore pressure on the vegetation and on the yew).

Table 2. Elements to consider when assessing herbivorism for establishing conservation measures.

DIAGNOSIS	PARAMETER	MEASURING ELEMENTS	METHOD
Forest	Habitat structure	Number of trees per hectare and species Number of shrubs per hectare and species (% of nurse plants) Average height of the tree and shrub layer	Forest inventory: fixed radius plots or transects
	Structure of yew population	Density (number of individuals/ha) Age structure: % adults, % juveniles, % Seedlings Sex ratio: Females / Males Youth ratio: % juveniles/adults	
Herbivore presence	Animal frequency	Directly: Number of animals per hectare and year, or Indirectly: Number of scats per hectare and year	Camera trapping or transects
Herbivore pressure on the habitat	Browsing pressure	Browsing extent of each species	Transect and application of browsing index (Table 2)
Herbivore pressure on the yew	Risk of herbivore pressure	% Juvenile yews browsed	Transects
	Browsing intensity	% Damaged branches/total branches of the yew	
	Browsing extent	% Loss in apical dominance (number of apical meristems/age of the yew) of yew	

The forest structure of the habitat tells us about the composition and density of the tree and shrub layers. In this case, knowledge of the shrub composition allows us to identify the presence of species with a nursing role for the yew. Together with the proportion of young yews in the grove, this information regarding the conservation state of the yew grove (table 1) allows management strategies to be established (table 1).

The presence of herbivores defined by frequency is important and can give us an idea of the possible herbivore pressure on the vegetation, enabling strategies to be determined for regulating or controlling livestock in particularly vulnerable areas. It would also be interesting to define the kinds of animal in question.

Herbivore pressure on the habitat or **browsing pressure** is an additional element to herbivore frequency, which allows us to differentiate the specific passing or shelter areas from the feeding areas. This is a semi-quantitative method that takes into account the extent of browsing on palatable species and species that are not very palatable or unpalatable (Taüll et al. 2011a,b) and consists in undertaking a transect where for each plant species with a height of below 1 m, the following data is recorded: (1) species name and (2) its level of consumption based on a score of 0 to 4 (0: not browsed; 1: some shoots eaten; 2: edible portion > portion consumed; 3: edible portion << portion consumed; 4: only edible parts left in inaccessible areas (interior part of the shrub). Afterwards, the species are identified based on whether or not they are palatable based on the knowledge of the plants' characteristics and the animals' preferences (for more information see: Taüll et Baiges, 2016), and a browsing value average is calculated for palatable species and another for species with low to zero palatability. Finally, using the values from table 2 the browsing intensity is given. The index is maximum when it is observed that certain plant species with low palatability are being heavily browsed. This is an objective method for determining the comparative browsing intensity of different areas..

Table 2. Estimate of browsing intensity based on the level of consumption of indicator species that are palatable and with low to zero palatability (Source: Taüll et al. 2011 b).

	Browsing intensity				
	none	weak	medium	strong	Very strong
Palatable species	1	2	3	3-4	4
Species with low to zero palatability	0	0	0-1	1-2	2-3

Herbivore pressure on the yew is determined from three elements: herbivory risk (% of juveniles browsed), browsing intensity (% damaged branches/total) and extent of browsing (% loss of apical dominance). We propose using the average value of these parameters to determine the conservation action to be taken (table 3).


Figure 1. Examples of high pressure from livestock (index 3-4) on the Mediterranean buckthorn (Rhamnus alaternus, a palatable species, on the left) and kermes oak (*Quercus coccifera*, not very palatable, on the right). Photos: Marc Taüll.

Figure 2. Construction of an exclusion fence in the Serra de Llaberia. Photo: Jarkov Reverté

Figure 3. Lamb trapped in a grazing exclusion fence. Game netting, with smaller holes at the bottom, may reduce the risk, but may also make it difficult for small animals to get through. Photo: Marc Taüll.

Figure 4. Individual guards for juvenile yews to protect against goats in the Cosp yew grove (Serra de Cardó). They are sized with the future growth of the yew in mind. Photo: Jordi Bas.

Figure 5. A few years after installing the fences or individual tree guards, the yew recover with shoots that can become quite vigorous. The photo shows a yew seedling just after the fence has been put in place (left) and 4 growing seasons later (right). Photos: Pere Casals and Jordi Bas.

5.6. Production and plantation of yew planting material

1. Description

The ex situ production of yew seedlings and companion species might be necessary to bolster populations, improve genetic connectivity or restore degraded yew groves. (see conservation actions 5.7). Based on the case history of the studied yew grove, different kinds of management actions are proposed, as well as different types of base planting material (table 1). In nature, the yew reproduces in two different ways, sexual and vegetative. Plant production, therefore, can be from seed, *in vitro* embryo culture or cuttings. For the effective conservation of the populations' genetic range, reproduction has to be from seed or *in vitro* culture.

Reproduction from seed is extremely slow in the natural environment, as the seeds present inhibitors or dormancy that can delay the germination process by up to three years. Seed dormancy is very complex and difficult to break, as there is both a morphological inhibition and another chemical one associated with the embryo. The germination protocol presented here was developed with the aim of producing plants from seed a year after their collection, in the second spring (Garcia-Martí 2007).

As the spread of the seed can be difficult, there are studies that have tried to develop in vitro cultures using seed embryos. Germination using this method takes place in 2-3 months with a 26-55 % germination success rate (Arregui 2007). In another study, germination took place in 15 days with an 85% success rate (Hosseini et al. 2011). Although this system constitutes a viable process for the large-scale production of yews, it is advised only to use it for specialised groups that have the necessary infrastructure for avoiding contamination and guaranteeing the seedlings' aftercare.

2. Aim

- To identify the most suitable conservation actions for a given population.
- To identify the type of base planting material to use for each action.
- To learn about plant production techniques from seed or vegetative multiplication.
- To learn techniques for planting and protecting seedlings in the forest.

3. *Ex situ* conservation techniques

Table 1 indicates the methodology to follow for plant production from seed or cuttings. The indications for transplanting them are laid out in section 4.

Table 1. Proposed actions for conservation management and types of base planting material based on the aims and diagnosis of the studied population.

Population diagnosis	Management action	Main aim	Types of base planting material	Destination of the plant
Lack of regeneration	**Population reinforcement**	Reinforce the non-reproductive age class. Creation of new populations, increase genetic variability.	**Seed**	The population or region of origin of the planting material.
		Reinforcement with specimens of known sexual expression.	**Vegetative multiplication (cuttings**	
Disappearance of a population	**Repopulation**	Very extensive repopulation using planting material from seed orchards or germplasm banks of the affected population or from the same region of origin.	***In vitro* culture**	
Fragmented populations from the same mountain range or nearby geographic area: 1) With low genetic exchange, vulnerable to potential accidents (fires, drought, etc.)	**Seed orchards: *quasi in situ***	Collection of individuals with greater biological value, increase of genetic exchange, seed production with less risk of endogamy.	**Vegetative multiplication (cuttings)**	Orchards located in environmental conditions that are similar to those where the tree is to be reintroduced. They could be close to or far from the population of origin.
2) With high or low genetic exchange, vulnerable to potential accidents (fires, droughts etc.).).	**Seed orchards: *circa situm***	Replica of examples of great biological value, collection of native plants, environmental education, future connectivity with the natural population.	**Vegetative multiplication (cuttings)**	Orchards located very close to populations of origin and outside the natural habitat: public or private gardens, agroforestal systems They do not necessarily have to simulate the environmental conditions of the population of origin.

The region of origin is the area or group of areas which present the same ecological conditions, where seed sources or stands have similar phenotypic or genetic characteristics, taking altitude restrictions into account when appropriate (RD 289/20013, art. 2.f). In the case of yews in the Spanish State, 46 areas can be identified, 5 of which are in Catalonia.

Figure 1. *Circa situm* yew seed orchard (Serra de Xiva, Valencia). A format for producing replicas of individual adults from natural yew populations in the province of Valencia. The main aim is to safeguard the genetic variation of the last yew populations in the central mountain ranges of Valencia, protecting them from possible disturbances, as well as obtaining quality seed for reinforcing populations. Photo: Xavier Garcia-Martí.

seed

Collection

- Origin: respect the regions of origin and applicable regulations.
- Season: gradually from September to October, wait for fruits to ripen and collect them directly from the tree.
- Method: take fruits from various fertile female trees. Slide your hand up the branches and collect the fruits in a bucket. Keep the material in the fridge (4ºC) until it is used.
- Traceability: properly label each individual, collection area and weight. Keep the traceability throughout the germination process until the seedlings are transplanted.

La recol•lecció de material vegetal (fruits, esqueixos etc.) és obligatori comunicar-ho i obtenir el certificat expedit per la Generalitat de Catalunya d'acord amb la Directiva 1999/105/CE1 i complir amb la normativa: RD289/20032 i D131/20123.

74 % de germinació amb llavor de bona qualitat.

Germination protocol

Extraction of the seed from the fruit: immediately after collections, since this can affect germination. This process is done by mechanically or manually removing the pulp, followed by rinsing the seeds in abundant water, discarding any that float. Finally they are dried at room temperature and stored in the fridge.

- Viability test for seed: the "tetrazoli" test.
- Seed pretreatment:
- Acid scarification (2 parts distilled water: 1 98% sulphuric acid, shaken constantly for 3.5 hours).
- Seeds are cleaned with distilled water and rinsed in a colander to extract the remains of the seed covering.
- Imbibition in distilled water for 24 hours.
- Stratification in moist peat (composition 60:30:10 peat:perlite:coco) between 0 - 4ºC and with high humidity levels (80-85%) for 4 months (an antifungal treatment can be applied with 0.072% himexazol if considered appropriate). The seed is buried at a depth of 2-3 cm.
- Leave seed trays under cover with 50% shade.
- They should germinate in the second spring (approximately, 18 months later).

Figura 2. Plàntules de teix a la safata de sembra. Foto: Jordi Bas.

Pricking out and cultivating

- Pricking out: after 2 months of germination, prick out the seedlings from the seed tray and plant them in individual 300cc self-pruning containers at a root depth of around 20 cm. Substrate composition: the same as the planting destination (Figura 4)
- Fertilisation: for the overall crop calculate 150:25:130 mg of N:P:K; part is used on the first day of pricking out (47.6 g/plant with a composition of 16:7:15 N:P:K) and the rest through sustained fertigation throughout the production process up to the hardening phase before they are transplanted to their destination.
- Hardening phase: in the nursery (early/mid October) the plants are hardened, reducing watering intensity and provoking moderate water stress, before planting the seedlings outside.

Vegetative multiplication

Collection

- **Origin:** Respect the regions of origin and applicable regulations.
- **Season:** November to February
- **Method:** from cuttings
- **Shoot cuttings:** 15-20 cm long and upt to 0.5 cm in diameter, collected from secondary branches with short internodes and lignified wood.
- **Traceability:** properly label each individual, collection area and weight. Keep the traceability throughout the germination process until the seedlings are transplanted.

Rooting protocol

- **Stimulation of the isogene:** application of hormones (Indole-3-butyric acid, AIB) in liquid form (2000 ppm for 30 seconds) and subsequently washed with water.

Pricking out and growing

- **Growing:** growing tables with 20ºC and 90% air humidity, under 30% shading mesh and with substrate with adequate drainage and high quantity of perlite (35%).
- **Fertilisation:** for the overall crop calculate 150:25:130 mg of N:P:K; part is used on the first day of pricking out (47.6 g/plant with a composition of 16:7:15 N:P:K) and the rest through sustained fertigation throughout the production process up to the hardening phase before they are transplanted to their destination.
- **Hardening phase:** in the nursery (early/mid October) the plants are hardened, reducing watering intensity and provoking moderate water stress, before planting the seedlings outside.

65-75 % d'arrelament

Genèticament seran iguals que l'individu donant !

[1]*Council Directive 1999/105/CE of 22 December 1999 on the commercialisation of forest reproductive material.*

[2]*Royal decree 289/2003, of 7 March, on the commercialisation of forest reproductive material.*

[3]*Decree 131/2012, of 23 October, which regulates the official Register of companies that supply planting material and establishes the authorisation, inscription and functioning norms, regulates planting material production and commercialisation activities and creates the catalogue of local varieties of agricultural interest in Cataloni*[a].

Figure 3. Counting seedlings that have just germinated in their containers (Life TAXUS). Solsonès Agricultural School. Photo: Jordi Bas.

Figure 4. Separating seedlings into individual containers (Life TAXUS). Solsonès Agricultural School. Photo: Jordi Bas.

4. Monitoring indicators

Throughout the process the seeds and seedlings must be labelled to be able to trace their origin at any time. Sometimes individual monitoring is carried out on the trees with the highest germination success rate and greater production from seed, as this can vary considerably among trees of the same population and of different years.

In each step of the production process the different successes are analysed: quantity of fruit per tree or population, percentage of viability, germination rate (figure 3), survival rate in the first three months after emergence, survival rate after each growing cycle.

In the last phase, when we have the seedlings in different trays, the trays must be properly labelled and diagrams should be made of the distribution of their origins to have greater certainty of their traceability. Daily or weekly visits should be made to the nursery to check the automatic watering system and detect any problems that may arise, such as the appearance of plagues or diseases. It is also advisable to remove any moss that may have grown during the time in the nursery.

5.7. Planting to reinforce and restore populations

1. Description

One of the biggest problems of Mediterranean yew groves is low regeneration density, especially in areas with more extreme climates. This may owe to several factors related with their reproductive biology (little relation between female and male trees; poor blossoming and seed production or low germination rate), strong pressure from herbivores or stochastic phenomena (disease, fire, drought, temperature increases). Thus, the conservation of yews may require the plant's ex situ conservation and planting with different aims in mind, such as to diversify age classes in a grove or improve tree density in new stands. In the Mediterranean region, the lack of yew regeneration might be due to the populations' fragmentation and genetic isolation. This fragmentation might be the consequence of climate change, which reduces the yews' potential habitats, or forest fires. For the latter, ex situ conservation and propagation is of even greater importance as it provides plant material that is representative of each area's ecotype, allowing restoration in the case of a forest fire. Thus, clonal seed orchards and seed orchards are useful resources for reinforcing species populations in order to ensure the short- and long-term conservation of the yew (Garcia-Martí 2006).

2. Aim

- To reinforce populations with poor regeneration or which have a shortage of trees from one or more age classes.
- To connect fragmented populations from a single mountain range or which are close to one another geographically.
- To restore yew groves that have been lost in large forest fires or other disturbances.

3. Proposed action

3.1. Acclimation

Several months before being planted, simulate a reduced water supply in the nursery to acclimate the plant material to the water stress of its destination.

3.2.Attaining the seedling

Seedlings need at least 2 years from germination. They come in trays (2-4 year-old plants) or individual containers (plants >5 years old).

3.3.Planting season

When sap flow has stopped. The best time is from October to December or in March, so as to avoid frosts.

Figure 1. Planting a two-year-old seedling on the external perimeter of the Cosp yew forest (Serra de Cardó). Photo: Jordi Bas.

3.4. Planting areas

The planting areas are chosen based on the following aims:

1. **Population reinforcement.** Stands with scant regeneration, particularly those with little age-class stratification.

2. **Connection of fragmented populations**. Plant in sites with favourable conditions, placing seedlings between stands that are genetically isolated and which have difficulties in spreading, such as those found at the bottom of gullies. Preferably plant seedlings at the top of slopes, close to hills and where different fauna pass (migratory birds, for example, or paths used by carnivores), where, once the yews become adults, they are exposed to the wind (for pollination) and animals (dispersal) (Fernández et al. 2015). A number of seedlings from different trees should be used to increase the likelihood of genetic exchange and a balanced sex ratio.

3. **Restoration of degraded yew groves**. Known populations that have been lost due to forest fires or other causes. A large number of seedlings must be provided, therefore requiring a high level of investment, carefully measured efforts and the selection of favourable sites that maximise efficiency.

3.5. Distribution of seedlings based on the biogeographic region of origin

Once the region of origin has been defined the planting can be distributed combining seedlings from neighbouring stands from the same hillside or sector of the mountain, due to the strong kinship structure and consanguinity of populations within the same stand (Chybicki et al 2011). Care should therefore be taken, since, in the Catalan coastal mountains, genetic differentiation has been found in trees that are relatively close to one another; at a distance of just a few kilometres in the case of Montseny, for example (González-Martínez et al. 2010, see chapter 4.6).

Some authors have stated that viable yew populations should occupy a minimum surface area of between 0.5-3 ha (Piovesan et al. 2009) and include at least 40 reproductive individuals with a similar sex ratio (Iszkuło et al. 2009). In Catalonia, the average yew grove size (2.5 ha) enters within this standard. However, in certain cases the flower or fruit producing adult individuals numbered below these figures, particularly in the Llaberia yew groves, for example, before the Life Taxus conservation work began.

3.6. Seedling protection

The temperament class of the yew is shade-tolerant. If possible, they should therefore be protected from direct sunlight. However, as they grow towards their juvenile state they need more sunlight (from 0.5 m in height according to Devaney et al. 2015) and it is better to plant them where there is abundant diffuse light and crown closure is not complete, to ensure the plant has better chances of growth in the dominant stratum. If necessary, pruning or light thinning can be carried out on neighbouring trees, both before planting or after, as the lateral branches of competitors tend to close the canopy completely (see conservation actions 5.2).

The plants must be protected from herbivores. To this end, there are three of four types of tree protection (see conservation actions 5.5):

1. **Individual guard**. It is best to install strong protection with iron rods and a mesh with a perimeter that is greater than that of the surrounding yews. They need to be large (1.3-1.5 m tall and around 50 cm wide), as they will remain in place until the plant is out of reach of ungulates. If possible, the competing herbaceous vegetation should be removed periodically from around the young seedlings.
2. **Mixed individual guard.** This is a device that combines defence with initial shading for areas exposed to direct sunlight. The individual guard is complemented with a lateral shading mesh measuring around 50 cm high, leaving part of the upper protective mesh free of shading mesh, as beyond this height the trees need more light (figure 2). Protective plants can also be planted around the seedling, which provide shade. This also reduces the plant's need for water, which is of great importance for its survival.

Figure 2. Mixed individual guard on regenerated yew exposed to direct sunlight. Photo: Pere Casals.

3. **Exclusion fences.** Sized out for the area to be protected and located where there is high pressure from ungulates.
4. **Protective plants.** Protection from shrubs, preferably thorny shrubs (García & Obeso 2003, see chapter 3.3). Dense shrubs already found in the habitat can be used, which protect the seedlings from direct sunlight during the first years after planting, and which, subsequently, naturally or through human intervention, are then outgrown by thriving yews, but continue to protect them from the trampling and browsing of herbivores. When the plant moves into its juvenile and adult state it might be necessary to carry out occasional thinning, if the protective plants hinder the yew's apical growth (see conservation actions 5.3).

3.7. Facilitator and companion species in the habitat

Other fruit-producing species could be planted that play a facilitator role in seed dispersal (see chapter 3.3.) or which are typical of the habitat being reinforced or restored. Companion plants are essential in cases of post-fire regeneration.

3.8. Supporting irrigation

Survival rates increase considerably if additional irrigation is applied through supporting irrigation systems during the first two years (García-Martí et al. 2015).

4. Contributing factors

Using yew seedlings produced in nurseries from plant material with the same region of origin guarantees the genetic origin of the seedlings. We propose the protocol described by García-Martí 2007, Ríos et al. 2015 and summarised in conservation actions 5.6.

Bear in mind that seed germination may be very low (12-30%), most probably due to summer drought. In good years, seed viability is estimated at between 50-65% (Ríos et al. 2015).

The survival rate of yews planted in areas affected by forest fires has been observed at around 40% in Guadalajara (Colomina et al. 2015).

5. Monitoring indicators

The survival of planted specimens depends on the choice of microenvironments, extreme weather conditions during the plants' first years of life and the preliminary silvicultural work which is undertaken, in which the preparation of companion vegetation should be highlighted, since these kinds of actions are as important as the introduction of new specimens. Equally, excessively drastic changes in conditions from shaded to exposed to light can have an influence (Perrin & Mitchell 2013, Ríos et al. 2015).

To monitor planting we recommend carrying out regular monitoring, at least once a year after the seedlings' growing season (summer-autumn) during the first years of life. It is advisable to use a plaque to identify a selection of yews to monitor. The plaque, hung from a stake, will greatly facilitate the job of finding each yew over the course of time.

5.8. Attracting yew fruit dispersers

1. Description

The only part of the yew which is not toxic is the red, fleshy aril, which it produces to disperse its seed through frugivorous birds, like thrushes, and carnivores. In fact, one of the key ecological processes in the distribution of yew groves and the abundance of yews is their fruit dispersal. The biological qualities and use of the space by the dispersing fauna, therefore, determines the quantity (number of seeds dispersed), quality (probability of seedling survival) and capacity of the dispersed seeds (Schupp, 1993, Jordan & Schupp 2000, García et al. 2015).

Two types of yew seed dispersers can be distinguished, based on their effective dispersal distance. The first are short-distance dispersers (carnivores and sedentary birds) which deposit the viable seeds in their droppings at the foot of the tree itself or a few dozen metres from the mother tree. The second type are long-distance dispersers, migratory species with a high movement capacity (thrushes and finches) and which, in theory at least, can deposit the viable seed at a greater distance from the mother tree and thereby aid the colonisation of new sites. The most significant period for fruit-eating birds coincides with the yew's fruiting season (September-October). Flocks of fruit-eating birds in migration are attracted by a wide variety of woody plants that produce fleshy fruits, so the greater the concentration of fruit from different species, the greater the probability of attraction and, therefore, dispersal (see chapter 3.3). However, in mixed woodlands containing Catalan yew groves, seed production is often scant and the visibility of the seed-producing plants poor due to strong competition from dominant trees (Camprodon et al. 2015). Fortunately, through the management of the habitat, seed production can be favoured, seed-producing shrubs and trees can be made more visible and dispersers attracted.

2. Aim

To favour natural seed dispersal through the attraction of frugivorous birds and also carnivores. An additional aim proposed is to reinforce fleshy fruit bearing plants and, therefore, improve the diversity and functional complexity of the habitat's flora.

3. Proposed action

To intervene mainly in areas where there are adult yew stands with the potential for good fruit production, but which produce very few or no seeds due to poor light conditions or stress.

3.1. Selective thinning to improve fruit-bearing plants

When the plant cover is very dense and the crowns of scotch pines, holm oaks and other tree species and, on occasion, vines like the sarsaparilla, cover the yews, they hinder their visibility and access for seed-dispersing birds and mammals.

This kind of selective thinning prioritises male trees and, especially, mother trees that are most likely to benefit from heavy thinning. It can be done in two phases (see data file 6.2). The removal of first and second-tier competitors increases the amount of sunlight that reaches the trees and helps to ripen the fruits (Hulme 1996, Svenning & Magard 1999), while at the same time increasing yew visibility due to anomalous dispersers.

Silvicultural action can also favour other fleshy fruit bearers, like holly, whitebeam, buckthorn or hawthorn, adapting the intensity of the thinning to the temperament of each species.

3.2. Plantació de plantes esquer

Reinforcement is recommended through the planting of fleshy fruit bearers which are not yews. These serve to attract birds and carnivores, especially for migrating and gregarious species (song thrush, mistle thrush, ring ouzel, wood pigeon and common chaffinch being the most abundant species). Concentrations of these species can be found where there are large fruit-bearing yew.

The "bait species" or facilitators are selected using flora inventories for each site and based on their abundance. The seeds collected are in the same region of origin, or if possible from the site where they are to be planted. In Life TAXUS the following species were planted, in different proportions based on the abundance recorded in the inventories: *Amelanchier ovalis, Arbutus unedo, Crataegus mononyna, Ilex aquifolium, Phillyrea latifolia, Sorbus aria, Sorbus domestica* and *Sorbus torminalis*. Two-year-old seedlings were planted in yew grove stands with few adult plants in order to attract firstly birds and secondly carnivores when bearing fruit, in the hope these would in turn act as dispersers of the yew fruit (Camprodon et al. 2015).

3.3. Birdbaths and feeders for attracting seed-dispersing birds and carnivores

They should be located close to good seeding yews. The availability of water is a limiting factor in Mediterranean limestone mountains where the yew groves are found. Small, existing water fountains and ponds can be improved and small birdbaths made from local limestone, which can be put in place to increase the attraction of yew fruit dispersing birds. However, these often dry up due to a shortage of rainfall and clog up with fallen leaves (Guixé et al., 2015), therefore implying a certain degree of maintenance through the provision of water and cleaning. The ponds must measure at least 2 x 2 x 0.5 m to contain sufficient water and so as not to clog up too quickly. They can be located at the base of large sloping slabs of stone, or a small irrigation channel can be used to bring water from a spring or hollowed area of rock that collects rainwater.

Yew arils from areas affected by fires can be collected and deposited in small feeders to favour the spread of the yew. Depending on the areas, as well as yew fruit, other attractive fleshy fruits could be put here like those from: savin junipers and junipers, rose bushes, hawthorn, holly, whitebeam, etc. These species can act as facilitators for the future recolonisation of the yew.

They can be placed in hollowed out rocks close to yew stands or in areas where they could serve to connect two yew stands. Alternatively platforms could be attached to the yews themselves made from natural materials such as bark or wood, which would integrate well into the forest. Once set up they can also be used to hold seeds in drier years, for example, from early September to mid-November.

Figure 1. The holly (*Ilex aquifolium*) is a species typically found in yew groves and facilitates the trees' spread. Photo: Jordi Bas.

Figure 2. Song thrushes (*Turdus philomelos*) in a limestone birdbath in the Terres de l'Ebre. Photo: Jarkov Reverté.

Figure 3. Wood pigeon (*Columba palumbus*) captured on a camera trap, feeding on arils left on a small platform to attract dispersers. Photo: Biodiversity Department, CTFC.

Figure 4. The presence of bird droppings or carnivore scat containing yew seeds is a positive sign of the effectiveness of the actions taken to increase dispersal. Miseclòs Yew forest (Alta Garrotxa) Photo: Jordi Camprodon

4. Contributing factors

Local flora inventories or small line transect samples can be used to find out the abundance of the different plants of interest and thereby make an informed selection.

Action should be taken in areas with a high yew density, especially those where forest work has been carried out to reduce competition. It is known that the yew's dispersing animals are attracted when the trees bear fruit, a time when large flocks of birds can often be found, particularly song thrush, mistle thrush and ring ouzel. In fact, significant differences have been observed between the abundance of dispersers in forests with yews without fruit and forests containing good fruit-bearing yews (Guixé et al. 2015).

5. Monitoring indicators

5.1. Selective thinning to improve fruit-bearing plants

The same variables measured –or an adaptation- for the competition regulation treatments (conservation actions 5.2).

5.2. Planting bait plants

The same variables measured –or an adaptation- for the competition regulation treatments (conservation actions 5.7).

5.3. Birdbaths and feeders for attracting seed-dispersing birds and carnivores

1. Visits to checking the conservation status of small infrastructures: water level and filling of water troughs, quantity of fruits consumed in feeders, damages.
2. Presence of nearby excrement with presence of yew fruit (and optional analysis of contents).
3. Phototrap to evaluate wildlife visits in drinking fountains and feeders: species, frequency of visits, behaviour.

5.4. Facilitating Companions

1. Density of tress and / or surface occupied by the species of shrubs that facilitate the germination and development of the yew tree seedlings.
2. Estimation of fructification by species (see Table 5.1).

Conservation status (Serra 2009): favourable, the area occupied by the facilitating species occupies more than 30% of the stand; unfavourable-inadequate, between 10 and 30% of the stand surface; unfavourable-bad, less than 10%.

5.5. Presence of seed predators

Direct or indirect census in stands of birds and mammals (rodents and wild boar) from:

1. Listening or transect stations and direct observation (birds) at strategic points (Guixé et al., 2015).
2. Count depredated seeds under female feet (mainly rodents).
3. 3. Photographic trapping of birds and mammals (Guixé et al., 2015).
4. 4. Live trapping of small mammals (complementary follow-up to obtain abundance data according to fruit and stand production).

Conservation status (adapted from Serra 2009): favourable, no mortalities have arisen from predators or trampling; unfavourable-inadequate, mortality in over 50% of seedlings through trampling or predators; unfavourable-poor, over 90% of seedlings are killed by trampling or predators.

5.6. Presence of dispersing fauna

Direct or indirect census in stands of birds and carnivores from:

1. Listening or transect stations and direct observation (birds) at strategic points (Guixé et al., 2015).
2. Photographic trapping of birds and mammals (Guixé et al., 2015).

A time of listening and / or observation that is constant in each zone analyzed is established. Carry out the censuses during the weeks of maximum fructification of the yew (October), without rain or wind and during the first hours of the morning or at dusk. Effort proposal: minimum of 10 listening stations of 10-20 minutes separated more than 300 m in yew forest. Apart, at least half of control stations in wooded areas without yew trees, at least 1 km away.

In the case of photographic trapping it is important to place two chambers per study area for about two months throughout the time of maximum fructification of the yew. It is important that the cameras are fast and with good image quality day and night to be able to quickly capture all species (from rodents and small birds to ungulates). The bait are fixed feeders with enough quantity of fruits that must be replenished. They are located about 5 meters from the camera, one of them raised on a tree and the other on the ground.

Conservation status (adapted from Serra 2009): favourable, diverse, stable or regularly occurring fauna dispersal species (migrants) community in which there is a number of dispersers proportional to the number of seeds produced in a multiannual follow-up; unfavourable-inadequate, very few specimens that can disperse shingle; unfavourable-bad, no seed dispersal species are found in the area.

5.9. Wildfire prevention

1. Description

The forest management that integrates wildfires prevention weigh heavily this objective, but in a synergic way with the improvement of other functions, like production. Management for fire prevention promotes the development of the tree cover in a particular way. This is, in a broad sense, in order to increase the forest capitalization, but is done through the creation of a forest structure that is suitable to management aims.

According to the ORGEST manuals, as described by Piqué et al. (2011) for Mediterranean forests, and in particular Beltrán et al. (2011) for Aleppo pine forests, Beltrán et al. (2012) for black pine or Vericat et al. (2011) for holm oak forests, the integration of wildfires into management is based on the study of factors that determine the fires and their relation with forests. The result is that the forest structure, i.e the distribution of vegetation that could serve as fuel, is the key factor for focusing silvicultural actions to make forests less vulnerable to wildfires.

The manual of Piqué et al. (2011) offers a classification of forest structures based on the vulnerability they present to develop a crown fire. Furthermore, following Costa et al. (2011), they also determine that, for some types of fires, certain sites are strategic for the development of large forest fires, making these places strategic for modifying the behaviour of fires through forest management.

The parameterisation of structural vulnerability is the basis for the design of management models for fire prevention, outlined in the ORGEST management manuals. A technical basis, therefore, has been established to design actions for forest fire prevention.

2. Aim

1. The goal is a fire spreading along the ground without affecting the crowns and becoming a large forest fire.
2. To modify the behaviour of a possible fire at specific strategic points to favour fire-fighting actions.
3. To integrate the protection of the yew grove in the massif scale. Since the surface area of yew groves is very small and these are habitats of great conservation interest, fire-fighting actions will not be taken inside of them to avoid modifying their structure, besides they would not be effective.

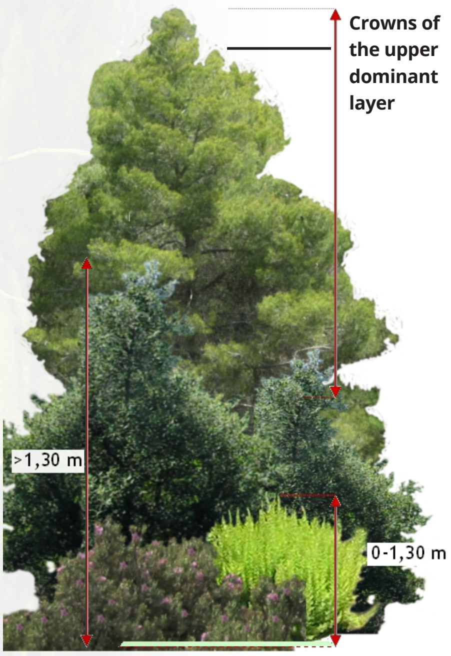
The management aims for wildfire prevention must, therefore, be achieved in two environments: 1) on a small scale, on the perimetral areas of yew groves, 2) in massif scale at strategic sites which may have an effect on yew groves, the so-called Strategic Management Points (SMP).

3. Management requirements

The above aim is achieved through the management and conservation of forests structures with a low vulnerability to crown fires.

The diagnosis of action areas should be done based on two factors:

1. **Locating strategic management points**. The aim here is to assess the possible effect of particular sites within the landscape (SMPs) on the behaviour of large forest fires that may affect yew groves. This analysis should be reflected in the different forest planning elements regarding a given area, such as for example, Priority Protection Perimeters, Fire Prevention Plans for Natural Areas (or other special areas) and even forest management plans at stand level.
2. **Analysis of the structural vulnerability to crown fires.** This is focused on assessing the structure of the forest in perimetral areas and in SMPs. All plant material that could potentially become fuel for wildfires is classified in layers and, subsequently, the degree of vulnerability generated by each layer and the vertical distance between them is determined. Figure 1 defines the different fuel layers.



AERIAL FUEL: Formed by tree crowns in the dominant or highest co-dominant layer

LADDER FUEL: Aerial fuels higher than 1.30 m that are not part of the dominant or co-dominant layer. Includes small trees, shrubs, vines or fallen trees.

SURFACE FUEL: CFuel found below 1.30 m of height. It could be shrubs, herbaceous vegetation, branches, fallen trunks, the remains of forestry work.

Figure 1. Definition of the fuel layers used for assessing the vulnerability of forest structures to develop and maintain crown fires (original from Beltrán et al., 2011).

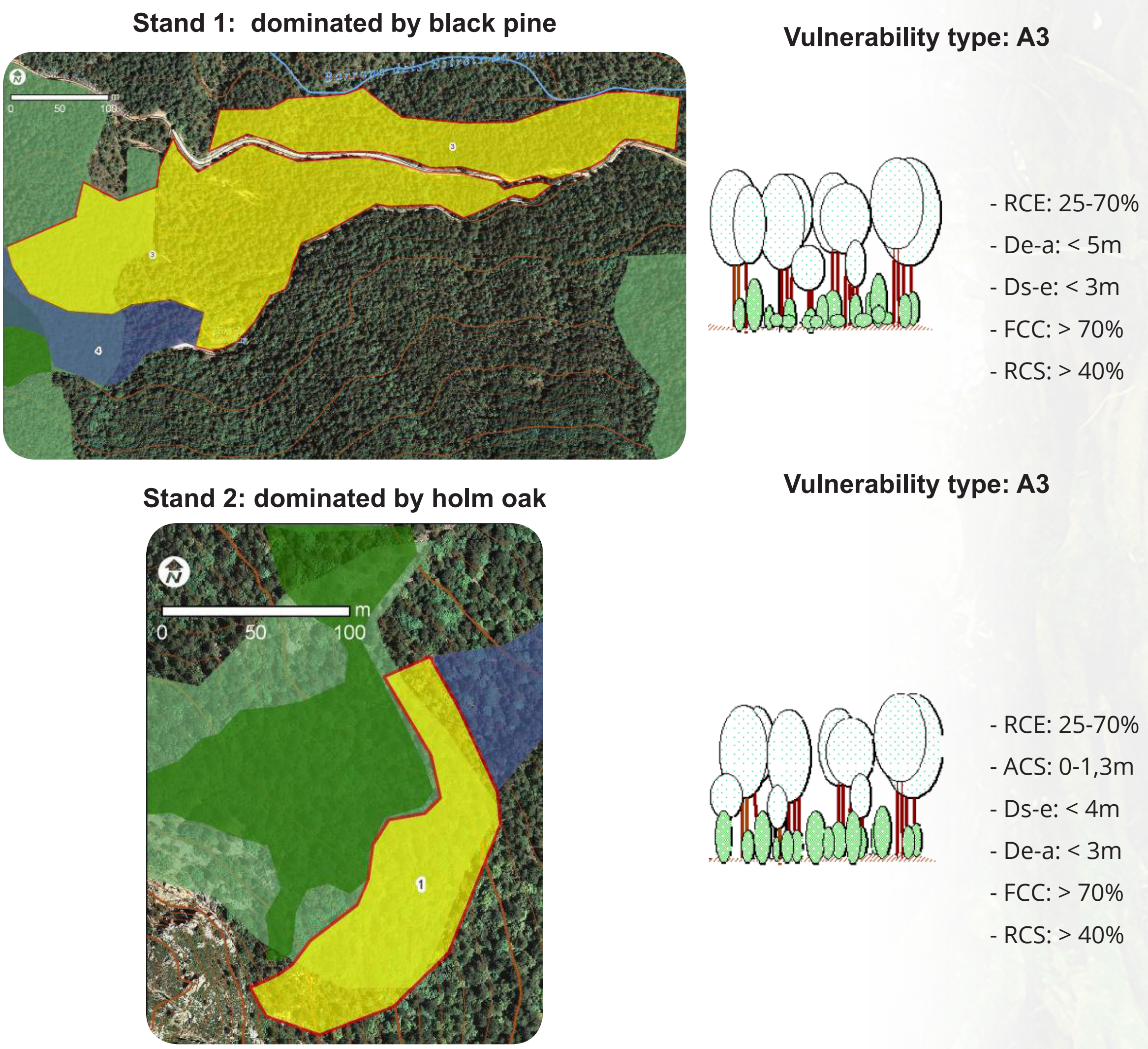
Once the fuel layers have been characterised, using the Keys for the Vulnerability to Crown Fires of Piqué et al. (2011), based on the dominant species, the vulnerability level of the analysed stand is determined. This information allows to assess the need to undertake actions for reducing this structural vulnerability. To define forest management actions for creating and maintaining low-vulnerability structures, the ORGEST management models are used as a reference, based on the dominant species.

In general, the ORGEST models are based on the idea that a well-developed tree canopy with an elevated base height can create conditions within the stand that hinder the development of ladder and surface fuel layers. If the shade created by large trees impedes shrub and small trees growth so that the surface and ladder fuel layers have little cover and are well separated vertically from the dominant canopy, the structure will be one of low vulnerability to crown fires.

3. Proposed action

As an example, let us look at the Serra de Llaberia yew grove. For the protection of this yew grove the following have been identified: 1) a distant stand but one located in a SMP defined in the Forest Fire Prevention Plan of the EIN of the Serra de Llaberia and which may have a significant impact on the yew grove; 2) a stand located in a perimetral area.

The forest classification for both stands is one of high structural vulnerability to crown fires. The first is a stand dominated by black pine while the second is dominated by holm oak. Figure 2 shows the perimeters of the stands and the structure parameters that gives them a high vulnerability to crown fires.



RCE: ladder fuel cover
ACS: surface fuel height
Ds-e: distance between surface and ladder layers
De-a: distance between ladder and aerial layers
FCC: aerial layer cover
RCS: surface fuel cover

Figure 2. Spatial delineation (in yellow) of the stands to be treated and classification of the structure according to the structural vulnerability of Piqué et al. (2011).

The long-term management goal is to create and maintain a low-vulnerability structure. The actions were planned based on the ORGEST models that have this goal, specifically the Qii06 and Pn08 models, from the manuals on holm oak (Vericat et al. 2011) and black pine (Beltrán et al. 2012).

Conceptually, the actions to be undertaken are defined as follows:

- **Stand 1:** reduce the ladder fuel cover (RCE) until 25% or less (high shrubs and dominated trees). Also the reduction in surface fuel cover (RCS) until 30% or less (low shrubs) in areas with low trees.
- **Stand 2:** reduce the RCE until 25% or less (high shrubs, dominated trees and branches below crown level).

The silvicultural definition of the actions is as follows:

- **Stand 1:** clearing the understory and low pruning of large broadleaf trees (includes the selective felling of specific minor trees across the entire surface area of the stand). Selective removal of shrubs with a height higher than 1.3 m throughout the stand, and other shrubs up to a cover of less than 30% in areas with less tree height (h <11 m). Minor trees (DBH <7.5 cm) are also felled if they have a live crown in a height lower than 1.3 m, with the exception of trees that are isolated and in viable black pine regeneration areas. In those areas the first-generation dominant pines are cut down. Throughout the stand, broadleaf trees with a height of more than 4.5 m are pruned, and most of the ivy on the tree is removed. Up to <25% of small holm oak cover and ivy on the tree should be respected.
- **Stand 2:** understory clearing, light thinning of shoots (selection coppice) and low pruning of broadleaf trees (includes the selective felling of specific minor trees across the entire surface area of the stand). Selective removal of shrubs with a height higher than 1.3 m and minor trees (DBH <7,5 cm) with a live crown in a height lower than 1.3 m, with the exception of isolated trees (primarily holm oak saplings and Italian maples). Dominated shoots are removed from holm oak and Italian maple stumps without cutting more than half of the total shoots per stump. Especially shoots covered in ivy or sarsaparille are removed. The remaining shoots are pruned to up to 1.5 m and branches that are not part of the main crown and create vertical continuity are also removed.

Up to 25% of RCE should be respected, distributed among the stumps of Mediterranean buckthorns and other woody fleshy-fruit producers, as well as certain ivies growing on the tree. All yew and holly trees have to be respected. In both stands the generated woody material measuring less than 5 cm in diameter are cut to a maximum length of 0.8-1 m. All others are cleared to the ground without them accumulating to above 30 cm. Any debris on the sides of the path is shredded.

As a result of these actions the forest structure is now classified as having low-vulnerability to crown fires, specifically with types C12/C9 for stand 1 and C17 for stand 2, according to the ORGEST classification system. Figure 3 shows the situation of forest structures before and after fire prevention management action was taken.

Figure 3. Images inside the stands, before the intervention and several months after. Before the intervention, both stands had structures of high-vulnerability to crown fires (A3). As a result of the actions taken, the structures now have low-vulnerability (C12/C9 and C17).

These actions have achieved the goal of creating low-vulnerability structures in a stand situated in the perimetral area of a yew grove and a stand located in a related SMP. They show how resistance to forest fires can be increased through integrated actions aimed at wildfire prevention in a single yew grove.

5.10. Soil stabilisation. Fighting against erosion

1. Description

Both the natural habitats of Mediterranean yew groves - steeply sloped ravines subject to frequent torrential rainfall - and the human activities that are often carried out there, are highly conducive to the erosion of habitats in general, particularly for large yews (see chapter 4.5).

2. Aim

To minimise the effects of erosion on yew populations and those of other plant species in the habitat in areas with an elevated risk of soil degradation

3. Action proposed

3.1. Prevention

Erosion is a process that feeds itself and is difficult to correct once initiated. Hence, the most efficient way to deal with the problem is to detect a risk of erosion and identify potentially erosive agents. A woodland's management must employ experts to assess whether the risk of erosion is due to natural causes or is man made. This should be done on different scales, looking at the landscape as a whole, small paths or particular monumental trees. The diagnosis would have to detect places or activities with a potential or actual risk of erosion, give specific guidelines for monitoring the risk in the short and medium term and define possible corrective measures.

Sites at particular risk of degradation from erosion that must be monitored

- Areas on a slope where the plant cover has been greatly reduced whether due to natural or anthropic causes. For example, sloping farmland, temporary fencing for livestock, areas burnt by fire or cleared areas.
- Areas with a concentration of livestock on flat or slightly sloping sites, such as those that are temporarily fenced where the animals can shelter from the sun and rest, where the compaction of the ground and browsing of the vegetation can begin erosive processes.
- Viewing points and their access, where frequent visitors can destroy shrub and herbaceous vegetation as well as compact and break up the ground.
- Paths leading out of woodlands where water can build up and begin to form rills.
- Long, steep tracks that cut across hillsides, which collect water runoff from the slope and channel it along the track increasing the erosive force of the water.
- Paths that run along the bottoms of ravines, where trampling causes compaction and small landslides on the hillside and the destruction of vegetation on the edges, to the extent that gullies can begin to form.
- Yews or other monumental trees where human presence at their bases can destroy the litter layer and compact the ground, reducing water infiltration, air entry and the incorporation of nutrients in the soil.

3.2.Corrective measures

This section outlines some corrective measures that are relatively simple to undertake. There are many more, with different application areas, degrees of complexity, technical difficulties and costs. A wide range of different treatments can be found in USDA (2006).

Sloping areas without vegetation that are susceptible to erosion

Figure 1. Fascines made from trunks or branches to stop surface water runoff and favour infiltration and retain sediment. To maximise their effectiveness the materials used should have good contact with the soil. Photo: Joan Llovet.

In areas that have been burnt by fire or cleared, fascines can be built with the remains of trunks and branches to avoid soil loss from surface water runoff (figure 1). This measure should be carried out during the months that lead up to the first spring after a forest fire (Serrasolses et al. 2004). For livestock enclosures a perimetral strip can be created from vegetation, fascines and wire or metal fencing that serves as a filter for runoff and favours infiltration. The perimeter should be closely monitored to check for drainage channels and correct the waterflow. The enclosure should be changed every few years to allow the site to recover.

Forest work in high-risk areas

Figure 2. Fascines used to prevent erosion in the Cosp yew grove (Serra de Cardó). Branches left over from work to regulate competition have been used (see data file 6.2). Photo: Jordi Camprodon.

The utmost care should be taken when carrying out conservation work, for example, in the use of machinery or ensuring that companion trees are not damaged, the roots of which play an important role in soil retention in high-risk conditions. Likewise, care should be taken not to damage yew seedlings or juveniles, which should be protected prior to any work being carried out on the site. Extraction tracks should be planned to avoid additional paths being formed. Once the works have been finished, any remains of vegetation should be collected into fascines, extraction routes should be broken up, using fascines or small stone walls to reduce the force of the water (figure 2).

Viewing points or areas with high human frequentation

Although aesthetically unnatural, it is advisable to construct a strong structure from wood or stone, for example, and delineate an access path to concentrate people’s footsteps and avoid a broader degradation of the environment.

Maintenance of tracks

Where possible, routes should be redirected away from areas with a high risk of erosion. Downhill shortcuts should be removed using deterrent barriers. For organised activities like races, the organisation should make it clear that participants that leave the path will be penalised.

Figure 3. Maintaining a path with low netting (30 cm high) of triple torsion galvanised steel, which runs along the lower part of the firm rocky layer and is anchored with galvanised steel wire to the railing bars as the hill rises. Cosp yew grove (Serra de Cardó). Photo: Jordi Camprodon.

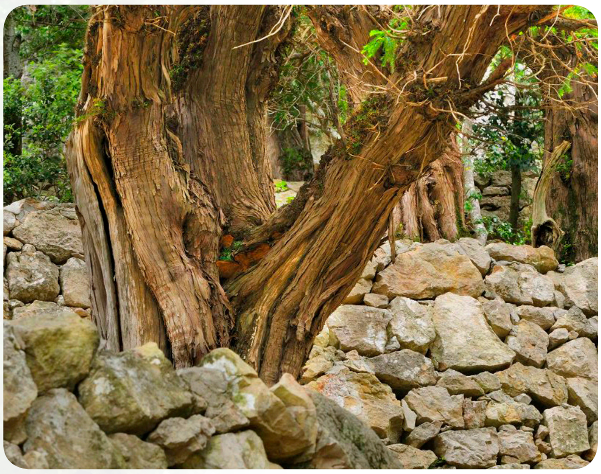
To condition the tracks or paths that access the yew grove or towards forest stands with a high presence of yews and which are subject to strong erosive processes, **fascines** can be put in place on the edges of the paths where there are steep slopes. When the paths become very steep, **steps** made from stone or trunks and stabilised with metal bars sunk into the ground diminish the erosive action of trampling. For stretches of steep scree slopes, the path can be protected from falling rocks with **low netting**. This has to be high enough to protect the path, minimising visual impact, avoiding large accumulations of rocks and minimising the effect on the scree dynamics (figure 3).

Figure 4. Drainage trough in a path, protected by wooden sleepers to break the flow of water across the middle of the path and drain the water. Parc Natural Font Roja, Alacant . Photo: Joan Llovet.

If possible paths should be avoided that traverse a slope without vegetation. In these cases, if the beginnings of erosion are detected, water should be prevented from entering the path, and should be collected using a **drainage ditch** dug parallel to the path, which channels the water towards an area with a lesser gradient and plant cover.

In order to break the flow of water in the middle of the path, the water should be removed using **drainage troughs**, channels with a bed of sand and compacted gravel, and wooden sleepers, with a width that allows them to be easily cleaned with a hoe (figure 4). In all cases, in addition to the slope of the path, a minimum inclination of 5% is needed to lead the water towards the ditch. The work should be complemented with settling containers for collecting the sediment and slowing down the waterflow.

Dry stone walls



Dry stone walls are structures that have been used all around the world since ancient times for creating agricultural terraces on steep slopes. They can be used to stabilise the soil around adult yews on steeply sloping hillsides (figure 5).

Figure 5. Dry stone walls used to protect centennial yews in the Cosp yew grove (Serra de Cardó), as part of an intervention promoted and financed by the Catalan Regional Government. Photo: Jordi Bas.

Intervention on slopes where rills are beginning to form

Figura 6. Dic de retenció. Mena de carreu construït amb pedres envoltades per una xarxa de filferro. Poden constituir una bona alternativa per protegir els camins en punts especialment febles.
Foto: Joan Llovet.

To avoid the long-term degradation of yew groves, where gullies are beginning to form the yew must be encouraged to grow towards the sides, where the erosive processes are not so severe. When the formation of rills is detected, action should be taken that includes channelling surface water. The channel should be filled with stones that facilitate the water drainage and reduce erosion on the edges. The erosion of the top part of the gully can be avoided using small **check dams** (figure 6).

4. Indicators for monitoring erosion and corrective measures

Among the most simple indicators for observing and monitoring the situation are:

- Root exposure may be the most obvious and easily detected indicator of a drop in the soil surface level.
- For paths, pay attention to the formation of gullies, landslides that modify the path's width and places where the path has been eaten away by downstream headward erosion.
- Changes in the path's surface level, manifested by a level reduction brought about by either compaction or material erosion, or a level rise in areas where the eroded materials accumulate. The drop in the path's surface level can be seen thanks to an increase in the height of the edges, but merely building the path produces raised edges that break the slope of the hillside; one thing is the existence of raised edges and another is their growth over time.
- Small movements and accumulations of leaf litter. Leaf litter is light in weight, being a material that can be easily moved by water, wind and other external forces. These cases

cannot be considered as indicators of actual degradation, but can indicate places exposed to external forces (figure 7).

- Increase in surface stoniness. This phenomena arises from the loss of fine materials, which are easily moved by the water or wind, leading to the accumulation of heavier and less mobile materials, such as stones, and eventually revealing outcrops of rock.
- The FAO has edited a series of guidelines for assessing the state of soil degradation. Some are relatively simple, and can normally be downloaded free of charge online. Some examples are:
    - *Field guide for rapid assessment of forest protective function for soil and water (can be accessed at http://www.fao.org/publications/card/es/c/0f4824f9-31db-4001-b80e-589333730c5a/)*
    - *Field measurement of soil erosion and runoff (http://www.fao.org/3/a-t0848s/index.html)*
    - *Guidelines for soil description http://www.fao.org/publications/card/es/c/0f070cdd-1b6d-53fa-add1-5c972fb299d2/).*

Figure 7. Displacement of leaves due to surface runoff. Photo: Joan Llovet.

5.11. Management proposals for the conservation of yew groves with regard to public use

1. Description

Both yew groves (habitat) and singular yews have the power to attract the wider public (tourists), nature lovers or people connected with the spiritual world (meditation, yoga, celtic culture, etc.). This attraction can be channeled towards raising awareness about the conservation of ecosystems. However, an excessive influx of visitors in these spaces that are limited in size, often on steep slopes, with thin soil cover and difficult to access, can hamper their conservation.

2. Aim

To give options for managers of yew groves (owners, municipal authorities, managers of natural spaces, associations, etc.) to enable them to establish a coherent action framework which is respectful of the yew grove.

3. Contributing factors

Yew groves with a certain level of public use may require both active and passive measures to be taken to ensure they are effectively protected. In general, regular supervision of the site (for example, every 3 or 6 months) may be sufficient for ensuring there are not alterations or excessive influx. In exceptional cases, such passive stewardship is not enough and active management mechanisms need to be undertaken. In any case, the principles that should govern the management of the public use of yew groves are the following:

3.1. Conservation principle

The yew grove is in itself the aim of the conservation and, therefore, actions should be aimed at preserving it and improving its status as a habitat. In other words, the conservation of yew groves is the main objective and cannot be overshadowed by the importance of attracting certain levels of visitors.

3.2. Prudence principle

The established measures, if necessary, should be agreed upon by all involved parties. It is not at all recommendable that one of the parties acts without first ensuring that other agents agree, even if they have the legal competence to do so.

3.3. Consensus principle

Les mesures que s'estableixin, si s'escauen, cal que siguin consensuades entre totes les parts implicades. No es gens recomanable que una de les parts actuï sense una posada en comú amb la resta d'agents, per molt que es disposi de la competència legal.

4. Proposed action

Below are a series of proposals, which should be evaluated for each case to determine their suitability.

4.1. Knowledge

4.1.1. Installation of visitor counters at path access points s

Quantifying and analysing visitor frequency during a minimum period of time (2-3 years) is the basis for understanding the magnitude of the problem, if there is one at all. This system helps to establish volumes, seasonality and peak visiting times (groups, gatherings, nature outings, etc.), which is, otherwise, difficult information to obtain.

4.1.2. *In situ* analysis of visitor behaviour inside yew groves

A field analysis to see what visitors do during their visit allows any harm that may be done to the habitat to be determined, to subsequently make recommendations regarding signage. In this regard it is better to choose days where a medium-high frequency is expected and avoid revealing information regarding who is the manager/owner/agent.

4.1.3. CCTV

When dealing with conflictive situations, the installation of camera traps or areas of video surveillance could be resorted to (for this the corresponding legal permits are necessary).

4.2. Actions to teach people about the yew grove

Certain yew groves with a very low frequentation can become a tourist resource for rural houses or local authorities. In such cases it is recommended to come to a good joint strategy, in which the value of exposing the resource to tourism should be assessed. In this regard, the inclusion of information on websites should also be assessed. The recommendations include ensuring that visits are good quality and that they provide some kind of return for the local population in the form of accommodation, restoration or visits to the village or town itself.

In line with respecting the “magic of the yew”, maintaining a certain degree of secrecy, automatically brings value to yew groves. This, in itself, should also therefore be part of any strategy.

4.3. Actions aimed at minimising the influx of visitors to yew groves

When it has been considered that an area has exceeded its visitor capacity or is close to doing so, a series of actions need to be taken. These actions have to be aimed at minimising:

1. The volume of people visiting the yew grove in question.
2. The impact that the visitors have on the habitat.

The following are action proposals focused on reducing the visitor numbers (developed from González 2015):

4.3.1. Limit vehicle access to nearby areas

The greater the distance between the parking and the yew grove, the fewer the visitors. Therefore, if the access can be regulated by, for example, closing off the track, while setting up a parking area that is not too close, visitor numbers should be brought down. In this regard, exceptions should be considered: nature should be within everyone’s reach and, therefore, people with disabilities should be able to access it.

4.3.2. Limit visitor numbers

This management option implies setting a daily quota of visitors, that may be constant or variable, and managing an online booking system so visitors can know, prior to their arrival, whether or not they can access the yew grove. This option requires a considerable degree of management: an online booking system, a single access point (or very few) and onsite control. This option is only advisable, therefore, if volumes are particularly high and the issue very complex. It is also advisable to limit visitor numbers to allow them more space and, as a result, offer them a more satisfying visiting experience. This, therefore, can also be seen as a measure that improves the quality of the visit. Finally, this measure should only be implemented in certain periods when visitor numbers are at their highest.

4.3.3. Pay to visit

This is a variation on the previous option, which should be applied if the aim is to minimise costs arising from an expensive management system in terms of staff. People are not happy if they pay money and no service is given in return, so an enriching visit should be organised, whether accompanied by a guide, with audio guides, signage material or something else. Another possible option is to charge for parking.

4.3.4. Control communication

One of the options that can be taken by managers of yew groves is not to give any kind of publicity, in other words, to ensure it does not appear on any maps, leaflets or other resources available to visitors. In this regard, it is also important to inform tourist offices that they are not to tell anyone about the location of the yew grove. In terms of resources that may appear on the Internet, from websites for nature walks to tree enthusiasts, it is more complicated to intervene and ask them not to publicise: although it is possible to minimise their presence.

Among the actions focused on reducing the impact visitors have on the habitat, besides the measures already proposed, are the following (developed from González 2015):

4.3.5. Visitor control

Defining paths and the physical presence of rangers may greatly minimise the impact on yew groves. There is a great difference between groups that walk all over the place and visitors that circulate around the space in an orderly fashion, following a set route, demonstrating appropriate behaviour, etc.

4.3.6. Defining paths

Instead of allowing free access throughout the yew grove, defining a path, ideally a circular one, with indications advising users not to leave the path, is one of the best options.

4.3.7. Signage

A panel showing recommendations for the visit and asking people to respect the environment should be enough in most cases

These measures for regulating public use are a first proposal of possible measures for effectively protecting yew groves and, especially, those that are most sensitive and furthest away from human influence.

Figure 1. Life TAXUS have installed information panels in gathering places away from the yew grove to reduce pressure inside the habitat, and at the same time reach a wider public regarding the natural values of yew groves and of the conservation work being carried out there. These panels can omit the exact location of the yew grove to avoid indiscriminate visits. Photos: Jordi Camprodon.

Figure 2. An example of an information panel in an area where conservation work is being carried out in a yew grove. Source: Poblet Natural Site of National Interest.

5.12. Adaptation to climate change

1. Description

Predictions of rising temperatures and increased periods of drought imply unsustainable levels of water stress for Catalan yew populations in the future, a situation made worse by the heightened risk of forest fires. Yew groves will likely experience a strong decline towards the end of the 21st century, which will be felt more greatly in southern mountain ranges. The more northerly yew groves will be able to maintain their ecological profile, with relatively little damage, with the exception of low-altitude populations, which will have to move to higher areas. In the long term, if conservation measures are not implemented, yews will eventually disappear from many areas of the Mediterranean region (Thomas & García-Martí 2015).

2. Aim

To increase the resilience and reduce the vulnerability of yew groves to climate change through management measures. Likewise, to facilitate the migration of populations towards areas with greater potential for adaptation according to the predictions drawn from distribution models.

3. Proposed action

Among the proposed actions to help yew groves deal with climate change are the following:

- Selective thinning to lower basal areas by around 10-20%, thus removing some of the competition, which in turn would increase the amount of light that reaches the yews and reduce water stress (Dahr et al. 2007, Ruprecht et al. 2010).
- Reinforce populations with seedlings from the same biogeographic area, to be protected from herbivores until they are of adult age by way of individual tree guards or exclusion fences.
- Monitor the evolution of populations, the vital status of individual trees, recruitment and sex ratio. Ideally yew populations should have a minimum surface area of 0.5-3.0 ha to be viable (Piovesan et al. 2009) with a minimum of 40 individuals with a similar ratio of males to females (Iszkulo et al. 2009).
- In order to alleviate stress and reduce the effects of high temperatures and drought in isolated adult yews with heritage value (monumental yews) or ecological value (mother trees) these can be watered and even shaded by planting a screen of protective trees.
- Facilitate assisted migration towards sites with better ecological conditions. This would imply the movement of seeds of southern origin to more northerly sites. The climate conditions of destination sites would be a key factor when deciding where to bring the seeds from. The warmer the area they are to be planted in, the further south the donor area can be. Given the broad genetic composition of yew populations, it is recommended to plant a high number of seedlings in the hope that at least some will be suitable for survival in their new environment (Thomas 2015).
- Prevent the effects of large forest fires in strategic management zones near yew groves.

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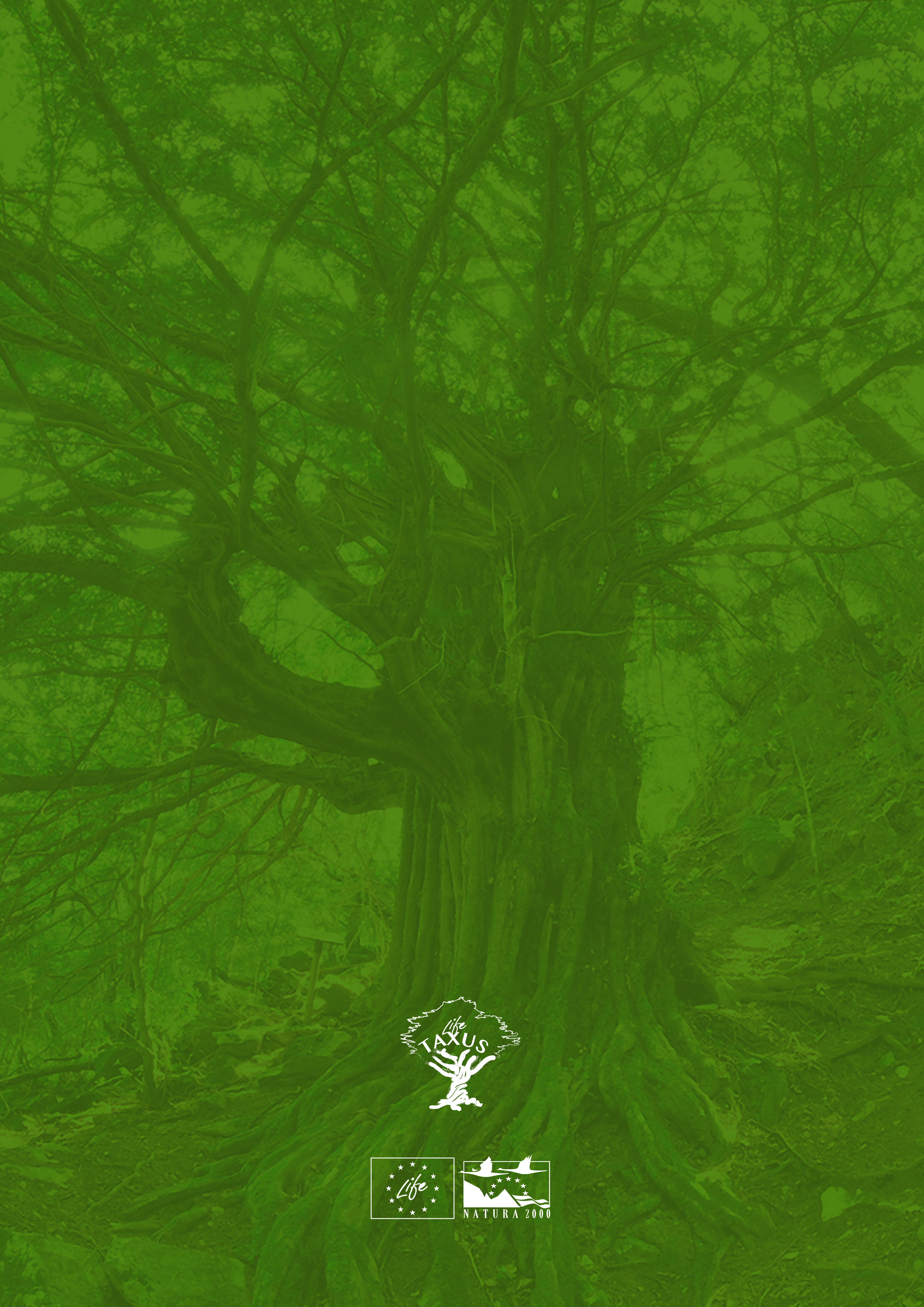
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