



The mosquito yew wood: Survey and analysis of Mediterranean *Taxus baccata* L. woods (Habitat 9580*)

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Abstract

Aim of study: To survey a yew tree grove and to evaluate its conservation status to ascertain whether its proposal to class it as Habitat 9580* is appropriate.

Area of study: Eastern end of Central Mountain Range, Spain.

Materials and methods: We conducted a field survey collecting data of UTM coordinates, altitude, orientation, companion woody species, height, stem perimeter, sex and browsing evidence. Individuals were classified in four age groups, considering height and stem perimeter: 1) seedling, 2) juvenile, 3), adult and 4) old. Companion species were analysed to assess the presence of habitat 9580* according to the Habitats Directive. Population structural complexity, stability and compactness were analysed to assess the conservation status.

Main results: We registered 8,304 yews along with seventeen distinctive accompanying species, thus confirming the presence of priority habitat of community interest 9580* "Mediterranean *Taxus baccata* woods". Population analysis leads us to appreciate a favourable conservation status for the whole habitat in the study area.

Research highlights: We have described the largest *T. baccata* grove registered to date in the Central Mountain Range of the Iberian Peninsula. We confirm the presence of priority habitat of community interest 9580* "Mediterranean *Taxus baccata* woods", being the first description of this habitat in the Community of Madrid. As the study area is located within a Special Area of Conservation (SAC), we propose its inclusion on the SAC habitats list.

Additional key words: Conservation; Habitats Directive; Natura 2000.

Authors' contributions: Project design and conception: PFG, AA, JB and FVE. Field Work: RBR, PFG, AA, JB and FVE. Data analysis and interpretation: AA and PFG. Cartography: PFG. Manuscript drafting: RBR. Critical revision: RBR, PFG, AA, JB and FVE.

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Introduction

Yew (*Taxus baccata* L.) is a conifer native to Europe that can be found over most areas, growing best in the oceanic climates with moderate temperatures. It is thought to be the oldest tree genus in Europe and individuals are very long lived. Yew is extremely toxic, which has led to its removal in many locations resulting in one of the largest declines of any European species. Thus, forest harbouring yew have been designated as special protection areas by the European Community (EC, 1992; Benham *et al.*, 2016).

In the Mediterranean region, yew habits in mountainous areas with favourable climatic conditions for the species. Being environmental humidity the main ecolo-

gical requirement, yew only occurs at locations where annual precipitation reaches at least 600 mm (Cortés *et al.*, 2000). For this reason, *T. baccata* presence in central and southern Iberian Peninsula is scattered, cohabiting in mixed mountain woods and rarely forming dense monospecific groves (Serra, 2009). Therefore, assuming that populations are in regression due to the increment not only in temperature but also the period of summer drought in mountain areas (Serra, 2007), yew is classified as a relictic species in the Mediterranean region (Arroyo *et al.*, 2004).

According to some authors (Cortés *et al.*, 2000; Serra, 2007; Iszkuło, 2011; Vessella *et al.*, 2015) herbivorous trampling and browsing are one of the main bottlenecks for populations regeneration. Regeneration dynamics was

recorded in some Central Mountain Range populations mainly due to rural land abandonment in the last decades and the decrease of livestock pressure (Balaguer-Romano *et al.*, 2020).

Atlantic and Mediterranean yew populations of the Iberian Peninsula are incorporated in Natura 2000 as habitat 9580* “*Mediterranean Taxus baccata* woods” listed as priority community interest in Annex I of Habitats Directive (Vaquero & Iglesias, 2007). Following the definition of the Interpretation Manual of European Union Habitats (EC, 2013), habitats 9580* are: “Woods dominated by *Taxus baccata*, often with *Ilex aquifolium*, of very local occurrence. This habitat type may have two origins: senescent phase of a beech wood or beech-fir wood, made up of clusters of *Taxus* after the fall of the tall species, surrounded by layered stands of beech-yew; residual *Taxus* stand with disappearance of the tall species, both above and in the proximity of *Taxus*”.

The above definition focuses exclusively on eurosiberian populations, as the reference to the presence of beech (*Fagus sylvatica* L.) and fir (*Abies alba* Mill.) woods indicates. In the Iberian Peninsula fir woods are located in the Cantabric and Pyrenees Mountain ranges only, while beeches are non-existent in purely Mediterranean areas.

Serra (2009) extends the definition to include a new origin type: “mixed woods dominated by *Taxus baccata* or deciduous species that coexist with it grouped in topographic situations that favour increased humidity and reduced insolation”. This extension of the definition incorporates the most common situations in which yew groves occur in the Iberian Mediterranean area, avoiding interpretation errors.

Due to the initial description, habitat 9580* Spanish cartography has been undervalued, discarding the mixed woods areas in where yew occurs. This is the case of the Community of Madrid (Spain), where the declaration of the SAC ES3110002 “Cuenca del río Lozoya y Sierra Norte” (BOCM, 2014), does not include habitat 9580*, despite the fact that Cortés *et al.* (2000) had previously cited more than a thousand yew trees on the area of “El Cuchillar” and “El Mosquito”, located in the northwestern Madrid region within the “Sierra del Rincón” Biosphere Reserve.

This background led us to survey in depth the yew trees in the area and to evaluate its population characteristics to support its classification as habitat 9580* with the aim of including it in the SAC ES3110002 “Cuenca del río Lozoya y Sierra Norte” habitats list. Regarding the previous estimate of “about one thousand yews” in the area (Cortés *et al.*, 2000) added to the well-known reduced livestock pressure along the last few decades, we anticipate both a larger population and a substantial regenerative demographic dynamics. Furthermore, we hoped that this population could have the structure and the accompanying species that would enable its classification as priority habitat of community interest 9580* “*Mediterranean Taxus baccata* woods”.

This study analyses yew survey from “*Censo y caracterización de la Tejada del Mosquito*” (AATT, 2021) with a focus on a description of the structure of the entire population and an analysis of the characteristics that would enable its classification as a priority habitat of community interest 9580*.

Material and methods

Study area

The study was conducted on an area of 265 hectares (Fig. 1a) in a mountainous zone with altitudes ranging from 1370 to 1900 meters at the eastern end of the Central Mountain Range of the Iberian Peninsula. Average annual precipitation varies irregularly from 600 to 1000 mm, softening the characteristic droughts of the Mediterranean summer. The study area is located in a sub-Mediterranean environment where the topographic diversity leads to the appearance of microclimatic zones with more favourable conditions for the development of Atlantic species such as oak, beech, birch or heather. In the 1990s, the area was included in Natura 2000 as Site of Community Importance (SCI) “Cuenca del Río Lozoya y Sierra Norte” (ES3110002), which in 2014 was finally classified as SAC. Although it is outside the study area, it is worth noting the proximity of “Hayedo de Montejo” natural area, classified as World Heritage Site by UNESCO.

Field measurements

Field work took 32 days between April 2017 and January 2020. An exhaustive census was carried out surveying all *Taxus baccata* individuals, excluding less than 5 cm high seedlings due to their high mortality rates. Data on UTM coordinates, altitude, slope and accompanying woody species (in a radius of five meters) were taken from each tree. Then tree height and stem perimeter at breast height were measured and sex and evidence of herbivorous browsing was estimated. Finally, according to Fernández-González *et al.* (2015) and Balaguer-Romano *et al.* (2020) specimens were classified in four classes considering height and stem perimeter: 1) seedling, lignified plants between 5 cm and 150 cm tall; 2) juvenile, trees taller than 150 cm and with stem perimeter up to 50 cm; 3) adult, trees with stem perimeter above 50 cm and less than 300 cm; and 4) old, trees with stem perimeters above 300 cm.

Data analysis

Core functions were used to represent gradual variation of tree density with the aim of assessing the popu-

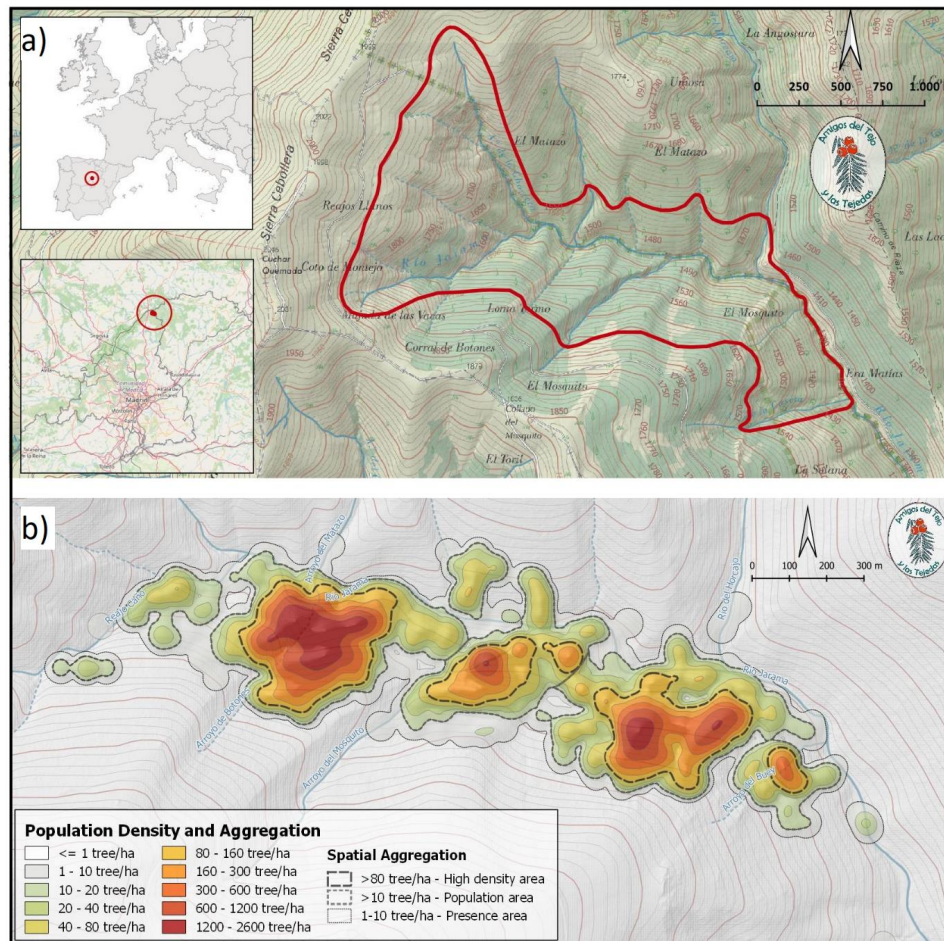


Figure 1. Study area (a); population density and spatial aggregation (b).

lation spatial distribution (De la Cruz & Maestre, 2013). To study population structure and neighbourhood relationships, a 25 m-side (540 m²) hexagonal mesh was established dividing the population area into homogeneous and easily comparable units. In order to obtain population dynamics we calculated a *Recruitment Rate* as the ratio between the sum of seedlings and juvenile trees and the whole individuals of the population (Schwendtner *et al.*, 2007; Balaguer-Romano *et al.*, 2020).

Habitat 9580* “Mediterranean *Taxus baccata* woods”

To assess the presence of habitat 9580* in the study area we analysed the characteristic accompanying species included in the Interpretation Manual of European Union Habitats (EC, 2013). Accompanying species information was completed with Serra (2009) and LIFE BACCATA project (García-Martí *et al.*, 2018) species lists.

We additionally carried out a set of analyses on population structure, stability and compactness to determine the conservation status of the habitat. These analyses were developed adapting the criteria established by Serra (2009) and Pescador *et al.* (2019).

Forest structural complexity aims to quantify the distribution of trees and their canopies. To evaluate it we have analysed tree height distribution, population density and the amount of different age classes for each of the cells established in the 25m-side (540 m²) hexagonal mesh. Canopy height was estimated with the average height of each cell, resulting in five categories (Table 1). Population density was estimated only considering the number of adult trees (class-3) per cell. We established five population density categories (Table 1). Finally, to assess age classes diversity we considered the number of different age classes and the dominant age class of each cell regarding the mode value. Again, we established five categories (Table 1). Then data was interpolated on the hexagonal cells establishing five classes of structural complexity (from very low to very high). Cells with high values correspond to areas where the height of the canopy is higher, adult tree density is higher and where it exists larger age classes diversity.

To assess population stability over time, it was assumed that stem perimeter is directly related to the age of the specimens. Thus, we estimated the median stem perimeter value of each cell and classified the stability in five categories (Table 1).

Table 1. Criteria for the establishment of the categories to evaluate population structure, stability and compactness.

	1) Very low	2) Low	3) Medium	4) High	5) Very high
Canopy height (m)	2-4	4-6	6-8.5	8.5-10	10-15
Population density (adult trees per cell)	1 tree	2-4 trees	5-8 trees	9-16 trees	17-19 trees
Age classes diversity	3 classes (mode 1)	3 classes (mode 2)	2 classes (mode 3)	3 classes (mode 3)	4 classes (mode 3)
Stem perimeter (cm)	75-100	100-150	150-200	200-275	275-400
Population compactness	1 side adjacent	2-3 sides adjacent	4 sides adjacent	5 sides adjacent	6 sides adjacent

To study population compactness and the edge effect, we analysed the number of sides of each hexagonal cell that were adjacent to another cell, only considering cells with presence of adult trees (class-3). So, population compactness of each cell was classified in five categories (Table 1).

Values were interpolated calculating the mean value of each cell considering population structural complexity, stability and compactness values. Then results were integrated into the hexagonal mesh to obtain a representation of the conservation status of the habitat, establishing a scale of four categories (Very Low = ≥ 0.25 and < 1.5 ; Low ≥ 1.5 and < 3 ; High ≥ 3 and < 4 ; and Very High ≥ 4) based on the accumulation of the evaluated criteria.

Results and discussion

We counted 8,304 yews with an average density of 150 trees/ha in the main core of the population (Fig. 1b). That is, to our knowledge, the largest yew grove recorded and measured along all Central Mountain Range of the Iberian Peninsula.

The classes distribution was 54% of class 1 individuals (4,472 seedlings), 36% of class 2 (3,007 juveniles), 9.9% of class 3 (820 adults) and 0.1% of class 4 (5 old trees). In relation with the sex of individuals, 898 specimens with clearly visible reproductive organs were recorded, 502 (56%) of which being female and 396 (44%) being male. The *Recruitment Rate* reached 0.9. These data show a strong regeneration dynamic, which is consistent with the observed in other populations of the Central Range (Balaguer-Romano *et al.*, 2020).

Browsing affected to 3,736 trees (45%), being seedlings and juveniles more affected than individuals of the upper classes. Domestic livestock pressure being acceptably low, the bulk of browsing is to be attributed to wild herbivores, mainly roe deer (*Capreolus capreolus*). This pressure is stronger in winter as yew is an evergreen species growing mainly in deciduous stands, bringing its foliage a valuable resource after autumn (Schwendtner *et al.*, 2007). This finding is consistent with literature, as several authors deem that the greatest demographic bottleneck for populations regeneration is seedlings mortality caused by herbivores browsing and trampling (Cortés *et al.*, 2000; Serra, 2007; Iszkuło, 2011; Vessella *et al.*, 2015).

The complete list of accompanying species reached 121 species (Annex [suppl]), being 17 of them distinctive of habitat 9580* (EC, 2013; García-Martí *et al.*, 2018). These species were: *Betula pubescens* Ehrh., *Corylus avellana* L., *Fagus sylvatica* L., *Ilex aquifolium* L., *Salix caprea* L., *Sorbus aria* L., *Sorbus aucuparia* L., *Taxus baccata* L., *Erica arborea* L., *Vaccinium myrtillus* L., *Aconitum vulpina* Rchb., *Galium rotundifolium* L., *Hepatica nobilis* Mill., *Melica uniflora* Retz., *Oxalis acetosella* L., *Polypodium vulgare* L., and *Viola riviniana* Rchb. These accompanying species confirm the presence of priority habitat of community interest 9580* "Mediterranean *Taxus baccata* woods", being the first description of this habitat to be recorded in the Community of Madrid.

Regarding the geographical situation of the population, it extends between 1400 and 1620 meters of altitude, with most of yew trees facing North in slopes ranging from 14% to 77%. This support that, in the Mediterranean region, the species finds favourable conditions for its biophysical requirements in mountainous areas with high altitudes, on streams or north-facing slopes that stay fresh and humid in summer with reduced drought (Sanchez-Martinez *et al.*, 2021). Accompanying species are typical of the Atlantic climate such as *F. sylvatica*, *C. avellana*, *I. aquifolium*, *V. myrtillus*, *Fraxinus excelsior*, *B. pubescens*, or *Quercus petraea*. The presence of these species indicates that the study area presents exceptional soil and environmental humidity levels within the Mediterranean region. We regard yew presence in the Iberian Mediterranean mountains as associated with areas where specific topographic characteristics favour forest diversity, leading to mixed woods in which yews are integrated. The presence of nurse plants, as *E. arborea* or *I. aquifolium*, facilitate seedlings growth (García *et al.*, 2000), the presence of fleshy fruit species, as *S. aucuparia*, increases seed dispersal birds activity (Serra, 2009) on both yew and other fruits and eventually yews dominate or co-dominate the mixed woods.

Article 1 of EC (1992), indicates that the conservation status of a habitat is deemed positive when there is a structure and functions necessary for its long-term maintenance, when its area of distribution is stable or has expanded and when the conservation status of its typical species is positive.

Thus, considering specimen's height distribution, adult trees (class-3) distribution and age class's diversity (Table 1), we established areas within the population in which the structural complexity was considered favourable for long-term population maintenance (Fig. 2a). Population age analysis, assuming a direct relationship between stem perimeter and specimen's age (Fig. 2b), together with the

Regeneration Rate data showing a strong regeneration ($Rr = 0.9$), lead us to believe that the habitat distribution area is firmly established and expanding. Finally, population compactness analysis focused on the absence of the edge effect (Fig. 2c) together with the previous criteria allows to establish two areas totalling 7.94 hectares where habitat 9580* is present with favourable conservation status (Fig. 2d).

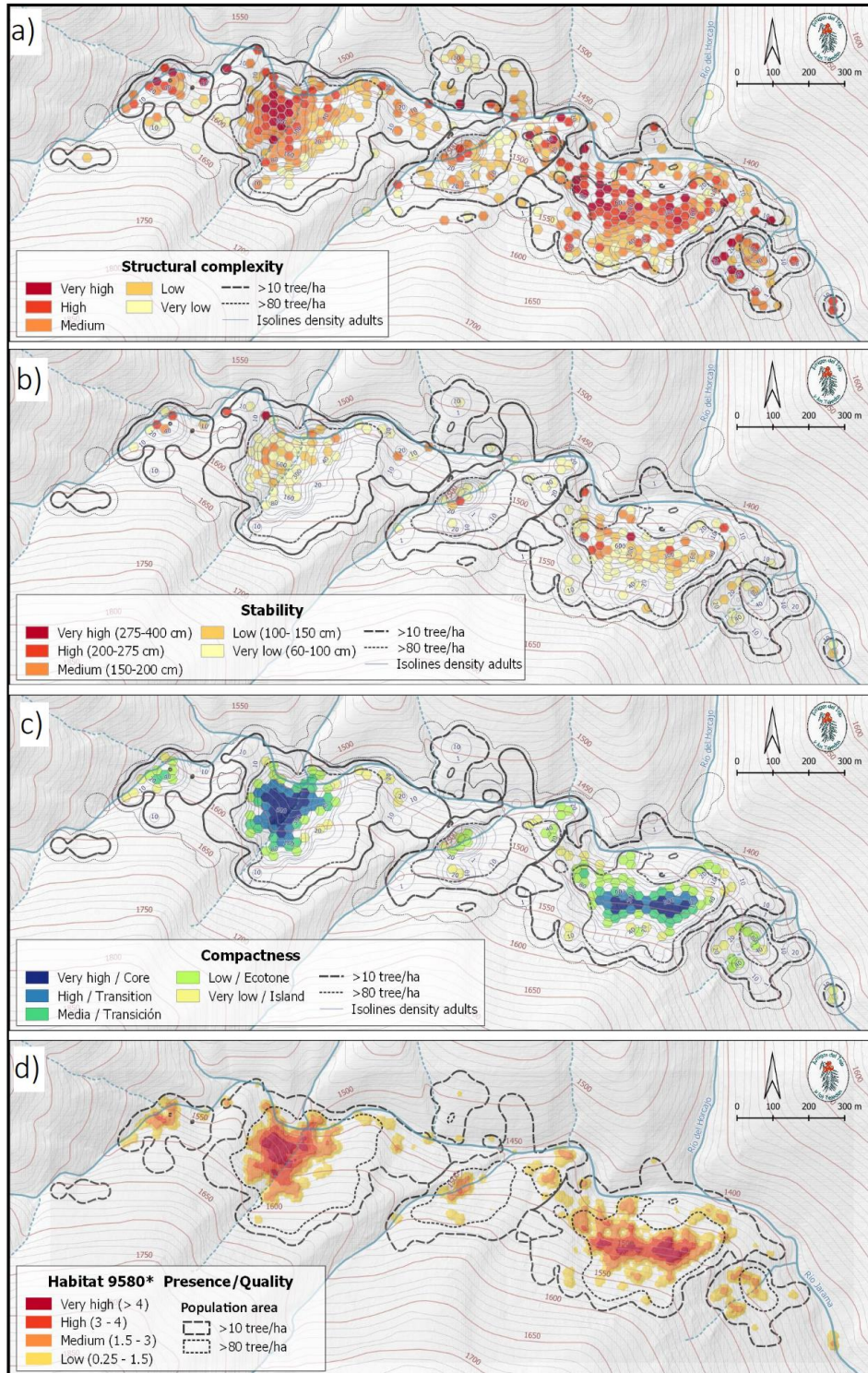


Figure 2. Population structural complexity analysis (a); population stability analysis (b); population compactness analysis (c) and Habitat 9580* presence and quality levels (d).

In conclusion, we described the largest *Taxus baccata* woods registered to date in the Central System of the Iberian Peninsula. Seventeen typical accompanying species have been cited, confirming the presence of priority habitat of community interest 9580* "Mediterranean *Taxus baccata* woods". It is the first description of this habitat in the Community of Madrid. As the study area is located within the SAC (ES3110002) "Cuenca del río Lozoya y Sierra Norte", we propose the inclusion of habitat 9580* in the SAC habitats list with its conservation status to be mentioned as good.

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