



## Breeding habitat preferences and reproductive success of Northern Goshawk (*Accipiter gentilis*) in exotic Eucalyptus plantations in southwestern Europe



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### ABSTRACT

With ongoing degradation of natural forests and spread of forest plantations, plantations must play an increasingly important role in biodiversity conservation. Study of habitat selection and reproductive success of surrogate species in plantations can guide forest management decisions for increasing biodiversity. In this paper we studied the suitability of exotic Eucalyptus plantations managed at low intensity in northwestern Spain as breeding habitat for Northern Goshawk (*Accipiter gentilis*), a top predator frequently considered a surrogate species in conservation.

Goshawks showed high breeding density, high reproductive success and a regular spatial distribution of nesting territories. Territoriality was the most important determinant of habitat selection. Goshawks selected extra-mature Eucalyptus trees in areas of high structural complexity (high tree density, tree species richness, and number of tree strata) in the most heterogeneous forest stands (old-mixed Eucalyptus). Reproductive success decreased with increasing local density of breeding pairs, but reproductive success was not related to structural characteristics of nest stands.

The studied plantations provided a suitable breeding habitat for Goshawks. The birds preferred to nest in large Eucalyptus trees with appropriate structure in their immediate surroundings. The strong preference of Goshawks for structurally mature forest patches may make them useful as a surrogate species for assessing the ability of forest management practices to promote overall biodiversity in exotic Eucalyptus plantations exploited at low intensity.

### 1. Introduction

Deforestation and forest degradation, major causes of global forest biodiversity loss (IUFRO, 2014), can be counteracted to some extent by forest plantations, which should play an increasingly important role in the provision of ecosystem services and biodiversity conservation (Brocknerhoff et al., 2008; Brocknerhoff et al., 2013; Trumbore, 2015). While global area of natural forest area has declined by 6% between 1990 and 2015, forest plantation area has increased by 66%, and it accounted for up to 7% of total forest area in 2015 (Keenan et al., 2015; FAO 2015). Most forest plantations (56%) are located in temperate latitudes, with more than half of these situated in Europe (Payn et al., 2015), where nearly half of plantations, mainly in central and southern regions of the continent, are made up of exotic species. In Spain and Portugal, the exotic species *Eucalyptus spp.* is particularly important; its

planted area has reached approximately one million ha, and it continues to increase (Martín-Vallejo, 2015).

The effects of forest plantations on biodiversity are still not fully understood (Bremer and Farley, 2010). Many forest plantations appear to be less diverse than natural forests, with a simpler composition and structure, particularly in even-aged, single-species stands involving exotic species managed in short rotation periods (Martínez-Jáuregui et al., 2016). On the other hand, certain plantations can provide a valuable habitat for a wide variety of taxa, including native, threatened and top predator species such as forest raptors (Petty, 1998; Sarasola and Negro, 2006; Speziale and Lambertucci, 2013; Olano et al., 2016). Analysis of plantations able to maintain species of conservation interest can help to identify forest management practices that favour biodiversity within plantations.

Top predators, such as forest raptors, are often associated with

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higher species richness because they usually select large-sized patches of habitat with relatively high primary productivity, structural complexity and spatial heterogeneity (Sergio et al., 2008). For this reason, dominant raptors can serve as surrogate species to represent the status of various species (Burgas et al., 2016) on a plantation and thereby inform comprehensive planning designed to support multiple species. Study of the relationship between breeding raptors and the composition and structure of forest plantations can help identify plantation characteristics that provide good-quality habitat for these species (Brocknerhoff et al., 2008). Forest management can then focus on improving the habitat for surrogate raptors, bringing benefits to a wider range of species and thereby improving overall biodiversity.

Habitat selection is a behavioural process based on innate or learned preferences through which individuals choose a habitat to settle, forage and/or reproduce (Robertson and Hutto, 2006). Habitat selection can be identified by the disproportionate use of some habitats compared to their availability in the environment, and it reveals essential requirements of the focal species (Johnson, 1980; Orians and Wittenberger, 1991). Breeding habitats should receive special attention because their availability is linked to long-term persistence of local populations (Boulinier et al., 2008). For birds, choosing nest location is critical because the nest must ensure concealment and protection during the long period from incubation to dispersal of fledglings (Orians and Wittenberger, 1991). Prevailing theory suggests that habitat preferences of animals are adaptive, such that fitness is higher in preferred habitats (Robertson and Hutto, 2006; Chalfoun and Schmidt, 2012; Fuller, 2012). Thus, we aimed to assess raptor habitat quality in forest plantations by focusing on breeding habitat selection and relating the observed habitat preferences to key demographic parameters such as reproductive success (Wilson et al., 2012).

In this study we analysed the suitability of exotic Eucalyptus plantations as a breeding habitat for top predators in northwestern Spain, using the Goshawk (*Accipiter gentilis*) as a model. We explored breeding habitat preferences of Goshawks at several spatial scales, asking whether they would select mature-like sites in Eucalyptus plantations, similar to their habitat preferences in other forest types. Then we assessed whether the observed breeding habitat preferences had adaptive value by testing whether they correlated with reproductive success. We expected that reproductive success would be greater, reflected in earlier laying dates and greater fledgling production, in preferred habitats. Identifying Goshawk breeding habitat preferences and understanding their relationship to reproductive success may guide forest management decisions to favour this top predator, thereby generating broader benefits for overall biodiversity in exotic Eucalyptus plantations.

## 2. Material and methods

### 2.1. Study area

The study area (183 km<sup>2</sup>) is located in northwestern Spain (Morrazo peninsula, Galicia, 42° 20' N, 8° 47' E). The climate is wet temperate oceanic (Cfb Köppen type) with annual average precipitation of 1402 mm and temperature of 14.2 °C (Cortizas and Alberti, 1999), and frequent wind and rain storms in winter and spring (Cabalar, 2005). The landscape is rugged, in that there are hills and valleys, with a mountainous axis with dominant direction SW-NE that divides the peninsula in a North and a South face. Average altitude is 169 m (range 0–628 m). The upper parts are occupied by gorse (*Ulex europaeus*) and rocky outcrops. Forests form a more or less continuous mass dominating the steeply sloping hillsides. Some small isolated forest patches within the agricultural matrix are also present. Lower parts of the hillsides and valley bottoms have been intensively cultivated and urbanised (Fig. A1 and Table A1 in the Appendix A). Human population density is high (480 inhabitants km<sup>-2</sup>).

Forest formations cover up to 51% of the study area, mainly exotic Eucalyptus plantations (*Eucalyptus globulus*), which began to be planted

at the end of the 19th century and nowadays represent 85% of the total forest area (IFN3, 1997–2007; Manuel- Valdés and Gil-Sánchez, 2006). The region comprises primarily private smallholding, giving rise to overall rudimentary, low-intensity forest management (Ambrosio et al., 2003). Each forest owner generally has fewer 61.5 ha of land, often distributed across several plots, 80% of which are smaller than 0.5 ha. Intensity of exploitation and mechanisation are low and silvicultural and phytosanitary treatments are rarely applied. Logging usually takes the form of clear-cuttings affecting small areas. The resulting forest landscape is a heterogeneous mosaic of small Eucalyptus plantations with different origins (plantation, resprouting), age and tree density, and rotation periods. Many abandoned parcels with extra-mature trees are present, often of unknown ownership (Ambrosio et al., 2003; Álvarez-Taboada 2005; IFN3, 1997–2007). Within these plantations, native tree species such as Pedunculate Oak (*Quercus robur*) and Laurel (*Laurus nobilis*), and other formerly introduced tree species such as Chestnut (*Castanea sativa*) and Pine (*Pinus pinaster*) are common, appearing clumped in certain plots, or ranged as tree lines along the boundaries between plots, or scattered as isolated individuals immersed within the Eucalyptus stands.

### 2.2. Study species

Goshawk (*Accipiter gentilis*) is a medium-sized diurnal forest raptor distributed across Europe and more widely globally in a Holarctic pattern. It is a generalist top predator that shows strong territorial behaviour with respect to both breeding territory and nest sites (Kenward, 2006). Goshawks use a wide range of habitats for nesting, including conifer and hardwood forests, and forest plantations (Kenward, 2006). They show preference for nesting in mature areas of extensive forests, although they also use small patches of woodland in fragmented agroforestry landscapes (Rutz et al., 2006). This species is sensitive to human activities, and it has been used as an ecological indicator of changes in ecosystems and effects of forest management (Crocker-Bedford, 1990; Reynolds et al., 1992; Widen 1997; Penteriani and Faivre, 2001; Mc Grath et al., 2003; Selås et al., 2008). Nest sites of Goshawks have also been associated with higher levels of biodiversity of several taxa, making them useful as a surrogate species in conservation (Sergio et al., 2006; Burgas et al., 2014, 2016).

### 2.3. Nest searches, laying dates and reproductive success

For the period 2004–2011, the entire forest area was systematically surveyed to locate all Goshawk nests (Pérez-Camacho et al., 2015; Rebollo et al., 2017a). Goshawk territories usually contain several nests that are used alternately over the years (Squires and Reynolds, 1997). Each nest was visited periodically during the breeding season to determine its occupancy (presence of breeders or their signs), presence of eggs (incubating female) or nestlings. On the basis of these observations, nests were classified, respectively, as occupied nests, active nests and successful nests.

Nestlings of successful nests were counted, measured and banded when they were older than 20 days ( $n = 263$ ; mean [ $\pm$  SD] nestling age at banding, 24.6  $\pm$  4.2 days). The minimal width of the tarsus was used to sex the chicks (males, < 6.5 mm; females, > 6.5 mm; Kenward, 2006) and the length of the seventh primary feather was used to estimate their age (Mañosa, 1994). Laying dates were estimated by subtracting the incubation time for a single egg (38 days) from the hatching date of the oldest nestling (Kenward, 2006). Earlier laying dates are related to greater reproductive success (Newton 1998; Byholm et al., 2002; Lehikoinen et al., 2013). The number of nestlings at banding was considered an indicator of fledging success (i.e. number of fully feathered young voluntarily leaving the nest for the first time; Steenhof and Newton, 2007) since the highest mortality of chicks usually occurs around hatching (Kostrzewa and Kostrzewa, 1990; Mañosa, 1991; Byholm, 2005).

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