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Traditional forest management: Do carabid beetles respond to human-created vegetation structures in an oak mosaic landscape?

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Abstract

We studied the effects of traditional forest management practices (i.e. forest exploitation activities such as burning, cutting and livestock grazing) on carabid beetle (Coleoptera, Carabidae) assemblages in Pyrenean oak forests of NW Spain. A total of 11 370 carabid individuals representing 61 species were collected by pitfall trapping from May to October 2004 in four types of traditionally managed oak ecosystems: ‘‘dehesa’’, ‘‘mature open’’, ‘‘mature closed’’ and ‘‘young’’. These four management types experienced a variety of anthropogenic activities, resulting in differences in the structure and composition of the tree and understorey vegetation layers. We showed that the four management types were quite similar at the carabid assemblage level, mainly supporting open habitat and generalist species. The ‘‘dehesa’’ system was most distinct with a higher species richness (not significantly) and with several unique species, probably travelling from the adjacent grassland. However, many species responded significantly to the type of management, depending on the habitat associations of the species. We also found strong responses of some of the species to one type of management, either positive (exclusively collected from one management type) or negatively (completely absent). Shrub cover and soil organic matter content were the main environmental variables determining the carabid assemblage structure. At the regional scale, the four management types accounted for a high carabid beetle diversity. This diversity appears to be threatened by landscape homogenization, since traditional management practices are disappearing due to recent land-use changes in the area.

Keywords: Carabidae; Forest management; Land-use history; Oak forest; *Quercus pyrenaica*; Understorey vegetation

1. Introduction

Forest management practices affect soil properties (Schmitz et al., 1998; Strandberg et al., 2005), the volume and quality of dead wood (Siitonen et al., 2000), litter accumulation rates (see Sayer, 2006), understorey composition (Szabo Kraft et al., 2004; Strandberg et al., 2005; Tárrega et al., 2006) and the vertical structure of the vegetation (Brokaw and Lent, 1999). Furthermore, the type and intensity of forest management can influence ecological processes such as nutrient cycling (Blanco et al., 2005), decomposition rates (Heneghan et al., 2004), vegetation regeneration (Uotila and Kouki, 2005), colonization processes (Hilmo et al., 2005) and predation rates (Nystrand and Granström, 2000). These changes affect organisms, either positively or negatively, depending on their habitat requirements (Martikainen et al., 2000; Martín and López, 2002; Pontégnie et al., 2005; Camprodon and Brotons, 2006).

Carabid beetles are sensitive indicators of forest management (Rainio and Niemelä, 2003). While detailed information about carabid responses to forestry practices in conifer plantations and boreal forests is available (Butterfield, 1997; Koivula, 2002; Magura et al., 2003; Koivula and Niemelä, 2003; Pihlaja et al., 2006), very little is known about their responses to forest management in deciduous forests (Werner and Raffa, 2000; du Bus de Warnaffe and Lebrun, 2004; Latty et al., 2006). Moreover, few studies dealing with carabids and forest management have taken the historical perspective of these anthropogenic activities into account (Latty et al., 2006). The lack of knowledge on the impacts of traditional forest exploitation on the carabid fauna is especially marked in historically modified landscapes, such as the Mediterranean area.

The distribution, structure and composition of forests in the Mediterranean area are a result of both traditional management practices (Pons and Quézel, 1985), and recent land-use changes

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(i.e. either abandonment or intensification) (García-Ruiz et al., 1996; Stoate et al., 2001). In NW Spain, the original Pyrenean oak (*Quercus pyrenaica*) forest structure is all but lost due to strong and repeated anthropogenic activities (i.e. fire, clear-cutting, thinning, livestock grazing) (Blanco et al., 1997; Luis-Calabuig et al., 2000). Generally, the present Pyrenean forest structure is characterised by a less dense canopy layer, high levels of light penetration, high shrub cover and the presence of fire adapted plants (Blanco et al., 1997). Irregular exploitation practices have resulted in a Pyrenean oak landscape mosaic of different and unevenly distributed stages of the same forest type. Each stage is the result of a specific management system and is recognised by a distinct vegetation structure and composition at the tree and understorey layers.

Here we investigate the effects of traditional Pyrenean oak forest management practices on carabid beetle assemblages in NW Spain, by studying the four most representative systems of oak exploitation in the area. The four selected types of management are (Table 1, Fig. 1): (1) ‘‘Dehesa’’—an extensive traditional oak management system currently used for pasture-land. It is characterised by scattered old-growth trees and few shrubs (the surrounding forested zone in Taboada et al., 2006). (2) ‘‘Mature open’’—a low intensity oak management system resulting from livestock grazing or firewood extraction, characterised by an open mature forest with few shrubs. (3) ‘‘Mature closed’’—a mature forest with a well developed shrub layer where anthropogenic uses have been abandoned. (4) ‘‘Young’’—an intensive oak management system resulting from secondary succession either after the abandonment of grazing and fire or after the felling or burning of mature forests. This system is characterised by young resprouting oak trees and high shrub cover. Even though detailed information on the specific management practices experienced by each oak system is lacking, distinct management types are easily recognised by their characteristic vegetation structure and composition (Fig. 1).

The aim of this study is to determine whether different management systems in the same oak landscape have had unique effects on the carabid beetle assemblage. We hypothesised that (1) if carabid beetles are more sensitive to management at the understorey level (shrub and herb layers), then the ‘‘dehesa’’ and ‘‘mature open’’ systems will be (a) similar in their carabid assemblages due to the openness of the understorey vegetation, and (b) different from the ‘‘mature closed’’ and ‘‘young’’ systems due to a more developed understorey layer (i.e. high shrub cover). (2) If carabid beetles are more sensitive to management at the tree level, then: the ‘‘dehesa’’, ‘‘mature open’’ and ‘‘mature closed’’ systems will be (a) more similar to one another in their carabid assemblages due to the presence of old-growth oak trees, and (b) different from the ‘‘young’’ system due to its coppice structure with smaller trees and more frequent anthropogenic disturbances.

Table 1
Management type characteristics (mean (±S.D.) values for each environmental variable are given)

	Management type			
	Dehesa	Mature open	Mature closed	Young
Site size ranges (ha)	11.50–24.64	20.97–91.91	32.24–83.97	29.24–177.38
Distance between sites (m)	7282.73 ± 3725.76	6965.24 ± 3547.22	6186.15 ± 4557.48	16111.56 ± 8821.37
Leaf litter and humus layer depth (cm)	2.72 ± 0.82	2.94 ± 0.42	3.96 ± 1.10	3.50 ± 1.66
pH	5.12 ± 0.20	4.88 ± 0.38	5.50 ± 0.39	5.20 ± 0.69
Soil organic matter content (%)	5.58 ± 1.63	9.10 ± 2.07	5.62 ± 0.96	6.05 ± 2.16
Oak tree height (m)	10.75 ± 1.98	14.42 ± 3.07	11.19 ± 2.96	4.88 ± 0.91
Oak tree perimeter (cm)	93.88 ± 18.79	89.45 ± 37.90	49.92 ± 15.98	22.56 ± 3.23
Oak tree canopy diameter (m)	6.70 ± 0.50	6.14 ± 1.68	3.95 ± 0.92	1.76 ± 0.20
Oak tree distance (m)	7.54 ± 1.47	4.10 ± 1.02	2.86 ± 0.53	2.27 ± 0.94
Oak tree sapling (<1 m height) cover (%)	5.03 ± 4.39	10.55 ± 7.71	22.87 ± 12.78	52.51 ± 14.39
Shrub cover (%)	8.61 ± 7.13	27.74 ± 16.78	56.78 ± 6.18	79.05 ± 20.17
Herb cover (%)	183.7 ± 27.21	111.15 ± 43.75	95.87 ± 30.75	74.78 ± 26.28
Number of shrub species	4.40 ± 3.58	7.60 ± 1.82	9.00 ± 1.87	8.40 ± 2.70
Number of herb species	51.20 ± 6.42	34.40 ± 9.96	36.60 ± 3.78	34.00 ± 11.51
Shrub species		*Lithodora diffusa*	*Erica arborea*	*Calluna vulgaris*, *Erica umbellata*
Herb species	*Agrostis capillaris*, *Aira caryophyllea*, *Carex muricata*, *Cerastium glomeratum*, *Cynosurus echinatus*, *Festuca rubra*, *Hieracium castellanum*, *Hieracium pilosella*, *Tuberaria guttata*, *Vulpia bromoides*	*Cruciata glabra*, *Festuca rubra*, *Holcus mollis*, *Melampyrum pratense*, *Physospermum cornubiense*, *Stellaria holostea*	*Brachypodium pinnatum*, *Cruciata glabra*, *Festuca rubra*, *Galium aparine*, *Holcus mollis*, *Melampyrum pratense*, *Vicia sativa*	*Avenula marginata*, *Brachypodium pinnatum*, *Festuca rubra*, *Galium aparine*, *Melampyrum pratense*

Soil features were measured from five samples per site (i.e. 25 samples per management type). Tree features were measured on 40 tree individuals per site (i.e. 10 reference points were selected every 8 m following two perpendicular transects in each site and we measured the closest four trees to each reference point, see Tárrega et al., 2006). Tree values were calculated on 200 observations per management type. Understorey vegetation features were visually estimated (see text). Cover values higher than 100% are due to layer superposition.