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Overview of environmental changes and human colonization in the Balearic Islands (Western Mediterranean) and their impacts on vegetation composition during the Holocene

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ABSTRACT

According to radiometric dates and the current state of research, the Balearic Islands were not colonized by humans prior to c. 4420/4220 cal yr BP. Therefore, it is possible to know the natural evolution of the landscape of the Balearic Islands for the first two-thirds of the Holocene (c. 10,000 to c. 4300 cal yr BP). This study aims to improve our understanding of the respective roles of human societies and/or climate in the transformation of vegetation cover during the Late Holocene in this Western Mediterranean archipelago. The results show the importance and control of climate oscillations in the evolution of vegetation throughout the Early and Middle Holocene. Our data clearly show that the transformation of the landscape started before the first human settlements. In Minorca (north-eastern Gymnesian Islands), this upheaval occurred between 5825 and 4675 cal yr BP (fourth to third millennium BC), while in Majorca (the largest of the Gymnesian Islands) the transition is less well dated, oscillating between 7169 and 2535 cal yr BP. In the southern Pityusic Islands, observed changes in Ibiza are less pronounced and coincide with the 4.2 cal kyr BP climate event, synchronous with human colonization. The correlation between forest fires and rapid climate events, as well as the resilience of vegetation until the Middle Ages (tenth century) in Ibiza, suggest that the evolution of climatic conditions is the preponderant parameter for explaining Holocene vegetation changes on these islands.

1. Introduction

Palaeoecological research focused on the Holocene has allowed for assessing the relationship between climate change and vegetation history. Generally, drying and cooling oscillations are documented during the Holocene, and a transition from wetter to drier conditions is observed in the Mediterranean area, which consolidated after the Middle-to-Late Holocene transition and affected the landscape configuration with the expansion of Mediterranean sclerophyllous woodland (Jalut et al., 2000; Roberts et al., 2001; Sadori and Narcisi, 2001; Carrión et al., 2010; Pérez-Obiol et al., 2011). However, there is debate about the causes of changes in vegetation evolution from the Neolithic onwards due to the increasing trend of human impact. The adoption of farming practices presupposes an alteration of natural landscapes and presents a remarkable new factor to consider when investigating palaeoenvironmental changes (Ruddiman, 2003; Ruddiman et al., 2015), and especially vegetation changes, as found in some pollen records from the Mediterranean area (Riera-Mora and Esteban-Amat, 1994; Sadori and Narcisi, 2001; Yll et al., 2003; Drescher-Schneider et al., 2007; Colombaroli et al., 2008; Kouli and Dermitzakis, 2008; Vannière et al., 2008; Vescovi et al., 2010; Marinova et al., 2012; Revelles et al., 2015).

Islands have always been considered ‘experimental laboratories’ for the detailed study of environmental change because of their high sensitivity (isolated areas and low resilience) to climatic and anthropic factors. Most studies have shown that the human colonization of islands contributed to environmental change and landscape transformation (Flenley et al., 1991; Dumont et al., 1998; Vigne, 1999; Prebble and Dowe, 2008). However, with more detailed research, it is possible to

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assess whether climatic factors were important variables in vegetation resilience (Athens et al., 2002; Sáez et al., 2009; Cañellas-Boltà et al., 2013; Rull et al., 2013, 2015). Distinguishing between the two aforementioned factors is often very difficult, especially considering possible sedimentary hiatuses and reversals in radiometric dating in the studied palaeoenvironmental sequences (e.g. Horrocks et al., 2013). This does not facilitate an understanding of natural landscape evolution and the role of humans in such changes. Our interest in the Balearic Islands stems from the fact that human presence is not attested until around c. 4320 cal yr BP (2500–2300 cal BC), with a population increase occurring around 3650 cal yr BP. The archipelago, with islands of small and medium dimensions (Table 1), is located in the Western Mediterranean (Fig. 1) and presents a typical Mediterranean climate (Table 1).

In Minorca and Mallorca, potential vegetation is typically Mediterranean, made up of Balearic evergreen oak forests (with *Quercus ilex* as the main component) and, in lower and windier areas, shrub formations related to thermo-Mediterranean forests (Peinado and Rivas-Martínez, 1987). These are dominated by *Olea europaea* var. *sylvestris*, *Prasium majus*, *Euphorbia dendroides*, and *Phillyrea rodriguezii* (Rivas-Martínez, 1987). The domain of the Phoenician juniper (*Juniperus phoenicea*) appears in Ibiza and Formentera.

This article summarizes pollen and anthracological results obtained up to now in the largest archipelago of the Western Mediterranean in archaeological and natural contexts. The fact that the Balearic Islands were uninhabited until the Late Holocene permits assessment of the climatic control of vegetation evolution in a Mediterranean area during the Middle Holocene. We aim to show the importance of climate in the Mediterranean Holocene landscape with or without human influence. Here, we i) evaluate the influence of climate change on vegetation evolution during the Middle-to-Late Holocene, ii) reconstruct the impact of human colonization on the landscape from the Late Holocene onwards, and iii) assess natural differences and compare climate change influence and vegetation evolution between the islands.

2. History of human occupation

Archaeological evidence from the Balearic Islands is relatively recent compared to other insular Mediterranean territories, and to date there are no vestiges from the Neolithic period (Micó, 2005, 2006). Nevertheless, the dates of the first occupation and permanent human settlement of these islands are not well defined yet. Although evidence reveals that humans arrived on these islands during the sixth millennium BP, the most detailed dates for their arrival range from 4850 to 4300 cal yr BP (2900–2350 cal yr BC) (Alcover, 2008; Guerrero and Calvo, 2008; Guerrero and Calvo, 2008). From then onwards, Chalcolithic settlements are developed on all the islands (Calvo et al., 2002; Calvo and Guerrero, 2002; Micó, 2006) (Table 2), but remains from this period are still rare. However, it is clear that around 4300–3800 cal yr BP a sedentary culture with demographic continuity throughout the archipelago developed, known as the Naviform (Middle Bronze Age) (Guerrero, 2007; Lull et al., 1999). It was from this time that cyclopean monumental architecture appeared with the generalization of navetiforms—megalithic structures forming the Naviform villages. These villages do not present surrounding walls or urban traces. Later, around 2850–2750 cal yr BP (900–800 cal yr BC), Naviform society experienced structural changes culminating in the birth of the Talayotic Culture (Early Iron Age) (Lull et al., 1999; Guerrero et al., 2002). This culture involved a monumental architecture of public buildings and varied typologies, with the so-called *talayots* being the most representative. From 2500 cal yr BP (550 cal yr BC), the destruction of some Talayotic villages is detected, as well as the diversification of funeral rituals and the emergence of new religious monuments. These changes led to the birth of post-Talayotic Culture (Late Iron Age), which extended until the Roman conquest of the Balearic Islands in 2073 cal yr BP (123 cal yr BC) (Lull et al., 1999; Guerrero et al., 2002). With this conquest, the Romanization of the archipelago began, which resulted in the creation of three cultural and economic focal points: the new cities of Palma, Pollentia, and Bocchoris. Roman domination lasted until 1416 cal yr BP (534 CE), when the Vandal conquest opened a period of instability with the domination of or relationship with Byzantium. This period ended with the conquest and domination of the archipelago by Muslims in 1048 cal yr BP (902 CE), and later in 721 cal yr BP (1229 CE) with the Christian conquest, which annexed the Balearic archipelago to the Catalano-Aragonese crown.

3. Reviewed sites and palaeovegetation data

These islands have not been widely studied from a palaeoenvironmental perspective. For this study, we selected the sites which have well-dated continuous palynological sequences (Fig. 1). From the island of Minorca, we selected the sites of Cala'n Porter (Yll et al., 1997; Carrión et al., 2012), Algendar (Yll et al., 1997; Pérez-Obiol and Sadori, 2007; Carrión et al., 2012), and Es Grau (Burjachs, 2006; Carrión et al., 2012). From Majorca, we chose the site of Albufera d'Alcúdia (Burjachs et al., 1994; Pérez-Obiol and Sadori, 2007; Carrión et al., 2012), while on Ibiza we selected the site of Prat de Vila (Yll et al., 2009; Carrión et al., 2012). In addition, the sites of Els Closos de Can Gaià, Son Ferrer (Picornell-Gelabert et al., 2012), Cas Canar (Llergo-López and Riera-Mora, 2010), Cornia Nou (Portillo et al., 2014), Cova de Sa Parra (Yll, 2011), and Cap de Barbaria-II (Revelles and Burjachs, 2015) were chosen, taking into account anthracological (Picornell-Gelabert, 2012) and pollen analyses conducted in archaeological contexts (Fig. 1).

3.1. Minorca

The three sequences studied on the island of Minorca are, first, Es Grau, which is particularly well dated; second, Algendar, which was the subject of a high-resolution analysis; and, third, Cala'n Porter, which is an incomplete sequence that includes, nevertheless, the moment of vegetation transition. These pollen sequences show an abrupt change in the composition of the vegetation between 5825 and 4675

Table 1
Data for localization, area, and climate ranges of the Balearic Islands (Western Mediterranean).

	GYMNESIAN			PITYUSIC	
	Minorca	Majorca	Cabrera	Ibiza	Formentera
Area (km^2)		3640	15	571	83
Coordinates	39° 59′ 08″ N 4° 06′ 53″ E	39° 37′ N 2° 57′ E	39° 09′ N 2° 57′ E	38° 59′ N 1° 26′ E	38° 42′ N 1° 27′ E
Highest elevation (masl)	358	1445	172	475	195
Average temperature in January (°C)	10.7	9.3	10.5	7–8	9–10
Average annual temperature (°C)	16.8	16	17	17.9	18.3
Average temperature in August (°C)	25	24.6	26	28–30	30–31
Temperature amplitude (°C)	14.3	15.3	15.5	18,2	20
Range of annual rainfall (mm)	592–654	402–1342	334–416	332–620	371–414
Evapotranspiration (l/yr)	848	839–864		820–920	880–940
Rainfall deficit (l/yr)	300–500				

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