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Research article

Socio-ecological adaptation to Early-Holocene sea-level rise in the western Mediterranean

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ABSTRACT

Consecutively to the global sea-level rise, coastal landscapes significantly changed during the Early Holocene. We explored how coastal mutations have affected ancient human systems in the western Mediterranean. The Pego-Oliva basin (Spain) provides a thick sediment sequence located in proximity to two well-studied Mesolithic and Neolithic archaeological sites. Based on 16 sediment cores, sedimentological analyses, ^{14}C dates, and integration of previous works, we reconstructed the architecture of the sedimentary facies and the chronology of deposition for the last 9500 years. From 9500 to 8200 cal. BP, the stepwise inland migration of the coastline is characterised by the deposition of peat layers at distinct depths indicating four phases of barrier-lagoon systems development. The marine transgression caused the disappearance of the lagoon at 8200 cal. BP, and reached a maximum inland position at 7300 cal. BP. Since 5800 cal. BP, sea-level stabilisation induced coastal progradation and barrier-lagoon system construction. Five marine flooding phases dated at 9500, 9100–9000, 8750–8650, 8450–8200, and 8100–7300 cal. BP match Atlantic meltwater pulses. Comparison to archaeology shows that the long-lasting Mesolithic occupation corresponds to the presence of coastal offering easily exploitable local intertidal resources. In contrast, during the Late Mesolithic, we observe a lagoon contraction and the reduction of lagoon bivalves size arguing for a decrease in resource productivity. This changes in the lagoon ecosystems negatively impacted to Late Mesolithic populations leading to a less intense occupation of this area. Therefore, the 700 years' temporal hiatus between the last hunter-gatherers and the first farmers occupying this area is explained by the disappearance of the formerly exploited biotopes because of sea-level rise, a situation that may have been aggravated by coincidence of the 8200 cal. BP climate event. The maximal sea transgression corresponded to a shift from intertidal to infralittoral species between the Impressa/Precardial and the Postcardial Neolithic, indicating a good adaptation to changing environments at that time. However, comparison between Late Mesolithic to Early Neolithic suggests that communities with different cultural baggage have had a different perception of the same environment. By the past perspective, it emphasises that perception of the ecosystem value as a benefit or constraint, and of the risks associated with sea-level rise, relies first on the local and regional scales adaptive capacity of society to global changes.

1. Introduction

Coupled paleoenvironmental and archaeological studies offer long-term perspectives of the resilience of societies to current global changes (Van de Noort, 2011). However, understanding how past humans interrelate to the environment further temporal comparisons between climatic, environmental and archaeological archives need to be implemented, by accessing the cascading set of socio-ecosystem responses from the global to the local scale. Following the end of the Last Glaciation, the coastal configuration profoundly changed resulting in the global sea-level rise flooding of the Late Pleistocene littoral plains (Shennan et al., 2000; Jakobsson et al., 2017). Sea-level rise was translated into the loss of human settlement areas, reduction of hunting territories, and modification of coastal ecosystems. Opposite views on whether coastal plains have been effectively attractive for prehistoric communities persist (Bailey, 2004). While some authors have proposed

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that Holocene coasts consisted of marginal areas, compared to the hinterland, others have argued for coastal landscapes as an interface between land and sea being places of countless opportunities for early humans (Dupont et al., 2009; Walsh, 2014; Benjamin et al., 2017). In the Mediterranean, marine resources have represented a low but significant part of the human dietary needs during the Early Holocene (Costa et al., 2003; Goude et al., 2017). However, the interaction between humans and their environments were not restricted to consumption purposes. Geomorphological heterogeneity and the associated biotic richness and diversity (Burnett et al., 1998) may have rendered these areas favourable for a large range of activities including shell gathering, fishing, hunting, agriculture and they well as offered easily accessible corridors for human movements (Erlandson, 2001). The issue is to determine to what extent Early to Mid-Holocene changes on coastal biotopes associated to sea-level rise have affected patterns of human exploitation and occupation (Colonese et al., 2011; Mannino et al., 2011; Colonese et al., 2018).

This work focuses on the paleogeographic reconstruction of coastal and human systems in the course of the Mesolithic and the Neolithic in the Pego-Oliva basin (Valencia, Spain). In the Western Mediterranean, recent studies have investigated human-environmental interactions during the prehistoric period (e.g. Dolez et al., 2015; Currás et al., 2017; Fontana et al., 2017; Vacchi et al., 2017; Melis et al., 2018). However, the low preservation of Early Holocene coastal sites as well as the paucity of integrated research programs correlating archaeological and palaeoenvironmental records, have prevented the answering of this question. Pego-Oliva area is a very well-adapted case study site for investigating the relationship between environmental changes and prehistoric socio-economic dynamics. This area provides sedimentary records to identify the coastal evolution from the Middle Pleistocene to the Holocene (Torres et al., 2014). Previous studies based on sedimentary and paleontological analyses have established the main trend of the morphogenetic evolution (Dupré et al., 1988; Viñals et al., 1989; Fumanal et al., 1993a, 1993b; Viñals, 1995; Viñals and Fumanal, 1995; Ballesteros Navarro et al., 2009), but are insufficient to be compared and contrasted to the human record given the low chronological resolution. In addition, the interest of this area lies in its proximity to two major archaeological sites. A renewed record has been produced, that includes dated Mesolithic human remains (Gibaja et al., 2015) and shell midden deposits (Fernández-López de Pablo, 2016), isotopic and zooarchaeological reconstructions of dietary patterns (García Guixé et al., 2006; Fernández-López de Pablo and Gabriel, 2016) and the discovery of Early Neolithic occupations containing rich mollusc assemblages (Esquembre-Bebia et al., 2008; Bernabeu and Martí, 2014), representing the introduction of farming dispersal episodes by seafaring pioneering groups. In this study, we first reconstruct the coastal morphogenetic evolution during the Early and Middle Holocene; then we compare the sedimentary evolution at Pego-Oliva with other Mediterranean sedimentary records to evaluate the driving forces (e.g. climate change) behind the Early Holocene relative sea-level changes, and finally, we explore how coastal mutation affected prehistoric settlement and subsistence patterns.

2. Study site

The study area is located in the south of the Valencian gulf in Western Mediterranean (Fig. 1A). This area is characterised by a succession of flat coastal plains occupied by lagoons (e.g. Albufera de Valencia) and marshes, interrupted to the south by sea cliffs (Viñals and Fumanal, 1995). The saltmarsh of Pego-Oliva is separated from sea by an 8 km long and 1.5 km wide sand barrier system parallel to the coastline. Several washover fans passing through the barrier are developed above the marsh. The saltmarsh is fed by two intermittent rivers fed by runoff, karstic springs and the ground-water nappe. The area is artificially drained for agricultural purposes and it is subjected to saline water intrusions resulting in groundwater exploitation (Ballesteros Navarro et al., 2009). Colluvial glacis (Fig. 1B) developed in the mountain feet are attributed to the Pleistocene (Viñals and Fumanal, 1995). A lower level of colluvial fans is partly developed on the marsh. The catchment is oriented SW-NE, dominated by Upper Cretaceous limestone mountains reaching 700 m a.s.l. The basin floor consists of Miocene formations (Fig. 1B). A thick Pleistocene sediment sequence is deposited below the sea level (Torres et al., 2014). Beachrocks attributed to the Early Holocene have been identified between −25 and 30 m (Fig. 1B) according to the previous stratigraphic correlation based on sediment cores and underwater seismic profiles (Somoza and Rey, 1991; Fumanal et al., 1993b; Rey and Fumanal, 1996).

The study area has been successively occupied by Mesolithic and Neolithic human communities during the Early to Mid-Holocene. El Collado is an open-air site that has uncovered a Mesolithic cemetery composed of 14 burials associated with a stratigraphic sequence containing lithic, faunal and shellfish assemblages. Several studies have been published on the stratigraphic sequence (Fernández-López de Pablo, 2016), lithic typology (Aparicio, 2014), chronology of the funerary practices (Gibaja et al., 2015), human diet (García Guixé et al., 2006), and exploitation of littoral resources (Fernández-López de Pablo and Gabriel, 2016). The chronological model of El Collado (Fernández-López de Pablo, 2016) integrates ^{14}C dates on human burials with dates from previous and posterior occupation horizons. This site includes two Early Mesolithic phases (level IV: 9830–9550 cal. BP and level II: 9435–8475 cal. BP) and one Late Mesolithic phase (level I: 8510–8390 cal. BP to 8500–8060 cal. BP). Despite an extensive program of dating, there is no evidence of Late Mesolithic occupation during and after the chronological span of the 8200 cal. BP event, suggesting the end of the human occupations at this time. El Barranquet is an open-air Early Neolithic site comprising two occupational phases (Esquembre-Bebia et al., 2008). The first phase, characterised by Impressa/Precardial pottery, has been dated at 7550–7320 cal. BP. Both the ceramic record and the chronology show strong cultural affinities with the *impressa* Neolithic facies documented in the Ligurian-Provencal arc, associated with the first spread of farming in the western Mediterranean (Bernabeu et al., 2009). The second phase (UE 74 and 71) corresponds to the Postcardial Neolithic which is dated in the region at 6800–6000 cal. BP by its decorative style. Preliminary works have provided paleodietary information from malacological assemblages (Luján Navas, 2016).

3. Material and methods

Six new boreholes were carried out in the Pego-Oliva basin in 2017 using a geotechnical piston corer comprising core segments of 50 cm and a 10 cm core catcher. The core segments were then stored in 60 cm-width boxes in a cold room (2 °C). The borehole locations were acquired by GPS and altitude is reported according to LIDAR data (altimetric accuracy of 0.3 cm) of the Institut Cartogràphic Valencià with mean sea-level as a benchmark (P17-2: N38.87124, W0.04462, 0.89 m; P17-3: N38.86138, W0.05557, 0.67 m; P17-4: N38.85476, W0.06613, 1.86 m; P17-5: N38.85556, W0.07360, 3 m; P17-7: N38.85790, W0.06142, 0.67 m; P17-8: N38.87569, W0.08774, 1.8 m). The lithostratigraphy has been described based on colour, texture, grain-size, and presence of macro-remains (plant debris, shells, gravels).

Thirty-nine volumetric samples were obtained from the different sedimentary facies from three representing cores (P17-3, P17-5, and P17-7) and homogenised. A volume of 5 cm^3 was dedicated to dry density and loss on ignition analyses. These samples were weighed, dried at 60 °C for 7 days, and weighed again to estimate the dry density. These samples were then ignited at 550 °C for 5 h (Meyers and Teranes, 2001) and weighed to measure the Total Organic Carbon (TOC), and then ignited again at 950 °C for 1 h to estimate the Total Inorganic Carbon (TIC). The remaining ignited fraction corresponds to the Non-Carbonate Inorganic Residue (NCIR). The remaining sample volume