Coastal landscape evolution of Corsica: palaeoenvironments, vegetation history and human impacts since the early Neolithic period

Revelles J.^{1,2,3}, Ghilardi M.⁴, Rossi V.⁵, Currás, A.⁶, López-Bultó, O.³, Brkojewitsch G.⁷, Vacchi, M.⁸.

¹Institut Català de Paleoecologia Humana i Evolució Social (IPHES), Zona Educacional 4, Campus Sescelades URV (Edifici W3), 43007 Tarragona, Spain.

²Universitat Rovira i Virgili (URV), Àrea de Prehistòria, Avinguda de Catalunya 35, 43002 Tarragona, Spain.

³Universitat Autònoma de Barcelona (UAB), Departament de Prehistòria, Edifici B Campus UAB, 08193 Bellaterra (Barcelona), Spain.

⁴CEREGE Aix Marseille University, CNRS UMR 7330, IRD, Collège de France, INRA. Europôle de l'Arbois BP 80 13545 Aix-en-Provence CEDEX 04, France.

⁵Dipartimento di Scienze Biologiche, Geologiche e Ambientali, Università di Bologna, Via Zamboni 67 40126, Bologna, Italy

⁶Institute of Heritage Sciences (Incipit); Spanish National Research Council (CSIC); Avda. de Vigo s/n, 15705 Santiago de Compostela, España

⁷Pôle archéologie préventive de Metz Métropole, chercheur associé sous-convention Aix-Marseille Université, CNRS, Centre Camille Julian, Aix-en-Provence, France, 5 rue du Château de l'Horloge BP 647 13094

⁸Dipartimento di Scienze Della Terra, Università di Pisa, Via S. Maria, 53, 56126, Pisa, Italy

Abstract

A multi-proxy investigation of sediment cores has enabled us to reconstruct the coastal environmental evolution of East-Central Corsica (the sites of Saint-Florent, Piantarella-Bonifacio and Palo-Solenzara) for the last 8000 years. The analytical methods comprise pollen (five original pollen diagrams), weight loss-on-ignition measurements, laser granulometry, and ostracod identification. In addition, 26 radiocarbon dates are used to provide a robust chronostratigraphy for the sedimentary sequences. The assessment of coastal landscape dynamics enables us to define the major morphological changes and to evaluate the complex interplay between climatic forcing and anthropogenic activity on the vegetation history of Corsica, within an archaeological context, since the early Neolithic period (~7.4 cal kyr BP). The major findings are that the first farmers reached Corsica by sea, and they encountered a coastal environment mainly composed of freshwater ponds located close to the shoreline. This specific paleoenvironmental

feature offered a favourable location for agriculture and for the development of permanent settlements where a subsistence economy was developed. Since the Middle Holocene, postglacial sea-level rise has caused major changes in local coastal environments, often characterized by salt intrusion into freshwater bodies. At the transition between the Mid and Late Holocene (~4.0 cal kyr BP), an increase in both salinity and aridity caused substantial landscape changes, mainly characterized by a further expansion of saline marshland, mainly occupied by *Chenopodiaceae*. The results also provide new insights into the role of *Erica* in the original Holocene vegetation of Corsica. Our data clearly indicate that an *Erica arborea* - *Quercus ilex* forest transition occurred before 6.3 cal kyr BP, significantly earlier than previously proposed. Finally, the earliest evidence of cereal cultivation is at ~7350 cal. kyr BP, and in addition we are better able to constrain the role of humans in the landscape dynamics of Corsica since the early Neolithic.

1. Introduction

Several previous studies have investigated the role of human colonization on environmental changes and landscape transformation of islands (e.g. Flenley et al., 1991; Vigne, 1999; Zeder, 2008; Prebble and Dowe, 2008; Carroll et al., 2012). This is because islands can be regarded as ‘experimental laboratories’ for the detailed study of environmental change, because they are highly sensitive to climatic and anthropogenic factors (“isolated” areas with low resilience) (Evans, 1973; Burney, 1997; Fitzhugh and Hunt, 1997). In this context, palaeoecological and geoarchaeological studies of the coastal areas of islands are recognized as a key to understanding Neolithic colonisation and the establishment of permanent settlements by the first farming societies (Walsh, 2014; Melis et al., 2018). The Mediterranean Islands have played a decisive role in the study of the Neolithisation process (Broodbank and Strasser, 1991; Zilhao, 1993; Ammerman and Davis, 2013). In fact, many of these islands were first colonised by farmers (Cherry, 1990) with consequent ecological impacts on the endemic fauna and flora. In this respect, the earliest evidence of cereal cultivation is documented during the 8th millennium BP in Sicily and Sardinia (Calò et al., 2012; Ucchesu et al., 2017).

Mediterranean coastal landscapes experienced significant modification due to Relative Sea-Level (RSL) rise and climate change since the Last Glacial Maximum (LGM, ~26.0 cal kyr BP; e.g. Goy et al., 2003; Amorosi et al., 2009). Pollen analysis is a valuable tool for documenting these processes, given the fact that the herbaceous and aquatic vegetation of coastal environments respond directly to salinity changes related to RSL variability (Primavera et al., 2011; Di Rita and Magri, 2012; Melis et al., 2018). Moreover, vegetation at a regional scale reflects climatic conditions and several Holocene dry and cooling events, with a general trend of increasing aridification and the expansion of xerophytic and sclerophyllous taxa, have been assessed for the

Mediterranean area (Jalut et al., 2009; Roberts et al., 2011). In the Western Mediterranean, several palaeoclimatic records document a warm Early Holocene, followed by a cooling trend (Alboran, Cacho et al., 2001; Minorca, Frigola et al., 2007; Gulf of Lions, Jalali et al., 2016), which affected the mid- to late-Holocene evolution of both the vegetation and depositional environments. However, the complex combination of climatic and anthropogenic factors since ~8.0 cal kyr BP often makes it difficult to distinguish the influence of these two variables on the Mediterranean landscape (de Beaulieu et al., 2005; Roberts et al., 2011; Fyfe et al., 2019).

In Corsica, the third largest Mediterranean island (Figure 1), the first evidence of Neolithic societies is dated to ~7.8 cal kyr BP (Lugliè, 2018), demonstrating the **rapid** colonisation of the island by the first farmers. However, despite this assumption (which lacks the support of robust paleoecological data), there is little evidence for the early development of agriculture from archaeobotanical records. The introduction of domesticated plants and animals would have resulted in significant landscape transformation in terms of rapid deforestation and the expansion of grassland, as shown by several studies of colonisation in insular contexts (Frenot et al., 2001; Connor et al., 2012). However, scarce palaeoecological data are available for this period in Corsica (despite the valuable work of M. Reille along the Corsican shoreline; Reille, 1984), and the earlier research was sometimes conducted without precise chronological control of the studied sequences, precluding detailed and reliable correlation of changes in vegetation, climate and human activity. Previous knowledge of vegetation history in Corsica is based on research by M. Reille in the 1970s-1990s, which was conducted in mountain areas (Reille, 1975, 1992a; Reille et al., 1999) in the eastern plain (Reille, 1984) and in the north (Reille, 1991, 1992a). Recent studies have provided new data for the eastern plain (Currás et al., 2017), for the last 5500 years, and have helped to fill the

gap in the south (southern islet of Cavallo, Poher et al., 2017) and in the western coast (Ghilardi et al., 2017). One of the main topics of discussion is the nature of the landscape prior to human occupation. To summarize this previous work, the dominance of *Erica* (identified as *Erica arborea*) during the Atlantic period (~9.0-6.0 cal kyr BP) from low and intermediate altitudes in Corsica raises the question of whether *Erica* formed scrubland, and hence whether an open vegetated landscape existed since the Early Holocene, or if forest was present, as suggested by Reille (1992a) and Reille et al. (1999). Subsequently, for the period 7.0-5.5 cal kyr BP, *Quercus ilex-coccifera* forest expanded, which has been also observed in other regions including Sicily (Calò et al., 2012, Noti et al., 2009, Tinner et al., 2009) and Malta (Djamali et al., 2013, Gambin et al., 2016), as the result of decreasing summer insolation leading to drier winters and moister summers, decreasing fire frequency, and consequently the **expansion-regression** of *Erica*.

In this study, we carried out an interdisciplinary investigation aiming at reconstructing interrelationships among landscape change, vegetation dynamics and human occupation along the Eastern-Central coasts of Corsica. We assess regional variability by comparing the available data with new records from sediment cores from the coastal areas of northern (Saint-Florent), eastern (Palo), and southern Corsica (Piantarella) (Fig. 1). Our objectives are i) to assess the impact of climate changes, sea-level rise and human activities on the Holocene evolution of the coastal environments of Corsica; and ii) to evaluate the role of Neolithic colonisers in vegetation modification of the island.

2. Environmental settings and archaeological background

The western coast of Corsica is characterized by rocky shorelines interrupted at the river mouths by coastal plains of limited extent. The topography of the eastern Corsican coast is generally flat, with large deltaic coastal plains formed by the major rivers (maximum length of 80 km) (Golo, Solenzara and Tavignano; Forzoni et al., 2015) that have isolated several large brackish-water lagoons located between Bastia and Porto Vecchio (Vacchi et al., 2017, 2018). The entire island has a microtidal regime and the tidal range does not exceed 0.45 m (SHOM, 2012).

2.1. Modern vegetation and climate

The climate of Corsica is characterized by a steep altitudinal gradient, from the warm and dry lower elevations (average annual temperature of ~14-17° C) to the cold and humid higher elevations (9-13° C). The climate of North Corsica is cooler and wetter, with a mean annual temperature of 15.5 °C and mean annual precipitation of 771 mm in Bastia (North Corsica); the climate of South Corsica is warmer and drier (16.4 °C and 542 mm in Bonifacio); and the climate of East Corsica is similar to that of the north (15.6°C and ~584 mm in Aléria).

Corsica is one of the most wooded islands in the Mediterranean and has a high diversity of environments, from the littoral zones to the mountain summits (Reille, 1992). The broad altitudinal range of the island results in several forest zones. The lowest elevations are characterized by the predominance of sclerophyllous evergreen oak forest (*Quercus ilex*, *Q. suber*) and Mediterranean scrubland (*Erica arborea*, *Pistacia lentiscus*, *Cistus monspeliensis* and *Juniperus phoenicea*). At intermediate elevations, mesophyllous pine forest (*Pinus pinaster*) is widespread, and mixed deciduous forest (*Quercus pubescens*, *Q. petraea*, *Ostrya carpinifolia*, *Alnus cordata*, *Castanea sativa*) is locally abundant. In Saint Florent (North Corsica), at the local scale various types of maquis occur, including stands of wild olive (*Olea europaea*) and lentisk (*Pistacia*

lentiscus) in the warm coastal areas; tall maquis with *Arbutus*; evergreen oak and heather (*Calluna vulgaris*) in the cooler areas; and low maquis dominated by *Cistus*, *Rosmarinus officinalis*, and *Lavandula stoechas* on poor soils (sands) and in rocky environments. The riverine forest consists mainly of alder (*Alnus*), willow (*Salix*) and poplar (*Populus*). At the local scale, l'étang de Palo (East Corsica) is occupied by *Salicornia* and *Atriplex* (Amaranthaceae), *Limonium vulgare* (Plumbaginaceae) and *Tamarix* in halophytic environments, and by *Alnus glutinosa*, *Prunus spinosa*, *Rubus ulmifolia* and *Pteridium aquilinum* in freshwater environments. At the extra-local scale, maquis predominates. L'étang de Piantarella (South Corsica) is occupied by Mediterranean maquis (*Cistus monspeliensis*, *Juniperus phoenicea*, *Pistacia lentiscus*, *Olea europaea*, *Arbutus unedo*) and marshland.

2.2. Previously documented vegetation history of Corsica

Due to the lack or scarce availability of radiocarbon dating in the classical studies conducted by M. Reille, the review of the vegetation history of Corsica (Reille, 1992a) is organised in terms of European Holocene pollen zones:

Atlantic period (7.5-5.0 kyr BP; ~9.0-6.0 cal kyr BP): dominance of *Erica arborea* at low and intermediate elevations and *Pinus laricio* at high elevations in western Corsica; and the dominance of *E. arborea* and deciduous oak forest in the eastern plain, consistent with the fact that eastern Corsica is still today the most humid part of the island with a less-marked summer drought. In the north, the region was exclusively covered with *E. arborea* forest, demonstrating that *Quercus ilex* forest did not exist during this period and that *E. arborea* was a climax tree in Corsica (Reille, 1992a).

Sub-boreal period (5.0-2.5 kyr BP; ~6.0-2.7 cal kyr BP): the major event in this phase was the expansion of *Q. ilex*, linked with Neolithic impacts on vegetation, according to

Reille (1984). The degradation of *E. arborea* forest by Neolithic communities would have led to the expansion of *Q. ilex*, an event documented in the northern coast, central and northern high-mountain areas, and in the eastern plain.

Sub-Atlantic period (2.0-0.0 kyr BP; ~2.7-0.0 cal kyr BP): major deforestation and progressively increasing human impacts, especially from 1500 cal yr BP onwards.

2.3. Archaeological background: Neolithisation in Corsica

The first human settlement in Corsica is marked by a sharp discontinuity between the Mesolithic and Neolithic (Lugliè, 2018). The first attested human presence is at the onset of the Holocene, consisting of hunter-gatherer communities that did not establish permanent settlements but rather occupied caves and other shelters. The earliest dates are documented at Strette (9140±300 ~~cal~~-yr BP, 11,135-9555 cal yr BP, Fig. 1) in North Corsica, and at Monte Leone (9750±175 ~~cal~~-yr BP, 11,761-10,591 cal yr BP, 8965±70 yr BP, and 10,249-9826 cal yr BP) in South Corsica (Figure 1, Lugliè, 2018). A gap in the population is documented during the transition from the 9th to the 8th millennium cal ~~yr~~-BP (probably associated with the 8.2 ka cooling event; Berger and Guilaine, 2009), and therefore agropastoral colonisation occurred in depopulated areas, as is confirmed by a genetic discontinuity between these two populations (Lugliè, 2018). The first Neolithic evidence is documented at ~7.8 cal kyr BP (Table 1), showing a rapid colonisation of the Island by the first farming societies. According to Tramonì and D'Anna (2016), the Middle Neolithic occurred during 6.8-5.9 cal kyr BP, with the first introduction of cattle husbandry (Wilkins, 2003). Since Middle Neolithic human settlements were concentrated in coastal regions and the nearby plains, Soula (2014) suggested that densification and demographic pressure would have intensified during the Late Neolithic (6.0-5.0 cal kyr BP), as testified by the appearance of dolmen and menhir typical of the European Megalithic Culture.

196

197 **3. Material and methods**

198 Sediment coring was carried out between 2015 and 2017 during which five sediment
199 cores were obtained, 3-7 m long, using a Cobra vibracorer with a hydraulic extraction
200 system (Table 2). The altitude of the boreholes with respect to mean sea level (m.s.l.)
201 was determined from a DGPS survey (Saint-Florent and Palo sites) and theodolite
202 measurements and was benchmarked to the local geodetic network (Piantarella site),
203 with a maximum final vertical error of ± 0.05 m.

204 Palaeoenvironmental reconstruction was performed using a multidisciplinary analysis of
205 sedimentological parameters, faunal assemblages and pollen content of the cores,
206 following the methodology successfully applied in several Mediterranean coastal
207 lagoons (e.g. Di Rita and Magri, 2009; Di Rita and Melis, 2013; Amorosi et al., 2013;
208 Avramidis et al., 2013; Fontana et al., 2017; Ghilardi et al., 2018).

209 **3.1. Chronology**

210 Twenty-six new AMS ^{14}C dates were obtained from marine/lagoonal shells, wood,
211 organic sediments, and macrofossils of Mediterranean seagrass (*Posidonia oceanica*)
212 (Table 3). These dates provide the chronological framework within which
213 palaeoecological and palaeoenvironmental changes across the study area can be
214 reconstructed and interpreted.

215 Because the production of atmospheric radiocarbon has varied through geological time,
216 radiocarbon ages were calibrated to provide dates in sidereal years with a 2σ range. All
217 samples were calibrated using Clam 2.2. (Blauw, 2010). We used a laboratory
218 multiplier of 1 with 95% confidence limits and employed the IntCal13 and Marine13
219 datasets (Reimer et al., 2013) for terrestrial and marine samples. Regional ΔR is 27 ± 32

(averaged values for this sector of the Mediterranean Sea; Taviani and Correggiari, in Reimer and McCormac, 2002). The site chronologies are described below.

Saint Florent

The dated samples are located at the depths of 88, 190, 232, 247, 445, 523 and 732 cm, and the ages are expressed as intercepts with 2σ ranges (Table 3). The age-depth model was built using interpolation (Fig. 2) and was used to plot the data illustrated in Figs. 5A, 5B, 8.

Palo

The dated samples are located at the depths of 90, 100, 143, 155, 161, 169 and 194 cm (Table 3). The seven dates are expressed as intercepts with 2σ ranges (Table 3). The age-depth model was built using the smooth spline interpolation method (Fig. 2) and was used to plot the data illustrated in Figs. 6A, 6B, 8.

Piantarella 1

The dated samples are located at the depths of 79, 191, 513 and 625 cm, and the four ages are expressed as intercepts with 2σ ranges (Table 3). The age-depth model was built using smoothing spline interpolation (Fig. 2) and was used to plot the data illustrated in Figs. 7A, 7B, 8.

Piantarella 2

The dated samples are located at the depths of 72, 124, 179 and 238 cm, and the four ages are expressed as intercepts with 2σ ranges (Table 3). The age-depth model was built using the interpolation method (Fig. 2) and it was used to plot the data illustrated in Figs. 7A, 7B, 8.

Piantarella 3

The dated samples are located at the depths of 266, 290, 360 and 388 cm (Table 3); however, pollen analysis was conducted up to 256 cm and therefore the age-depth relationship was extended across the undated 10-cm interval. The four dates are expressed as intercepts with 2σ ranges (Table 3) and the age-depth model was built using smoothing spline interpolation (Fig. 2) and was used to plot the data illustrated in Figs. 7A, 7B, 8.

3.2. Bio-stratigraphic analysis

Sedimentology

Samples were taken at 5-cm intervals. Loss-on-ignition (LOI) measurements were made at CEREGE, following the methods of Dean (1974) and Bengtsson and Enell (1986). Sediment samples of ~1 g weight were taken at 10-cm intervals throughout the sequence. After drying at 105°C to constant weight, the samples were heated to 550°C for 7 h to estimate the organic matter content. A second heating phase, to 950°C for a further 7 h, was undertaken to assess the proportion of carbonate. Many samples contained coarse particles (gravels) (>2 mm) and wet-sieving was conducted to isolate the coarse (>2 mm) and fine fractions (<2 mm). For the layers consisting exclusively of fine particles (<2 mm), laser diffraction grain-size analyses were undertaken (Ghilardi et al., 2014) using a Beckman Coulter LS 13 320 laser granulometer with a measurement range of 0.04-2000 μm , comprising 116 bins detected by 132 detectors (126 detectors for the scattering pattern and six detectors for PIDS (Polarization Intensity Differential Scattering) technology which is sensitive to sub-micron-sized particles). The calculation model (software version 5.01) uses Fraunhofer and Mie theory. For the calculation model, water was used as the medium (RI = 1.33 at 20 °C)

and a refractive index in the range of kaolinite for the solid phase (RI = 1.56; Buurman et al., 1996). Samples containing fine particles were diluted, and therefore measured between 8 and 12% of obscuration and between 45 and 70% PIDS obscuration.

Faunal assemblages

All samples were wet-sieved through a mesh screen (0.40 mm) and then air dried at room temperature. The residues were examined under a binocular microscope at $\times 10$ magnification and all shell and identifiable fragments were selected and placed in separate plastic tubes for qualitative identification. Based on the molluscan classification system that assigns Mediterranean species to well-defined ecological groups (Péres and Picard, 1964; Péres, 1982), bio-sedimentary units were then distinguished.

In addition, ostracod faunal analysis was performed on a total of 69 sub-samples to support and refine the palaeoenvironmental interpretation and the changes in depositional environments along the studied successions. Ostracods are an excellent palaeoenvironmental proxy, especially within coastal-margin settings and in geoarchaeological contexts (e.g. Pint and Frenzel, 2017; Barbieri and Vaiani, 2018; Kaniewski et al., 2018). In this study, two reference cores were selected (Piantarella 1-P1 and Saint Florent-SF; Fig. 1), taking into account: (i) their location on the opposite sides of Corsica; (ii) the thickness of the cored interval (6-7 m), as P1 and SF are the longest cores within the dataset; and (iii) the high recovery rate and variability of the sedimentological features. The selection of samples within each core (28 samples from core P1 and 41 samples from core SF) was performed in order to characterize the entire range of sedimentary units and to potentially detect high-frequency palaeoenvironmental variations (average vertical spacing of ~ 20 cm). Sample preparation followed the standard procedures described by Amorosi et al. (2014) and

Rossi et al. (2017). Each sample (~2-10 g) was oven-dried at 40 °C for 8 h, rinsed in water, wet sieved through a 63 µm sieve (240 mesh) and dried again. The resulting residue (> 63 µm) was qualitatively observed under the stereoscope and, if ostracods were present, dry sieved through a 125 µm sieve to concentrate the adult valves.

Following Whatley (1988) and Boomer and Eisenhauer (2002), the degree of autochthony was evaluated on the basis of the preservation status of each specimen and the population structure of each species. Twenty-seven samples showed an autochthonous ostracod fauna and the >125 µm fraction was quantitatively analysed. Where possible, at least 100 well-preserved ostracod valves were counted (a carapace was counted as two valves); otherwise all valves retrieved were counted (counting tables are available in the Supplementary Material – Tables S1 and S2). Ostracod specimens were mainly identified and counted at species level under the stereoscope, relying upon several key publications (Henderson, 1990; Montenegro and Pugliese, 1996). The relative abundances (%) of the taxa were calculated for each sample and four ostracod ecological groups (EGs) were established following Mazzini et al. (2017) and references therein. According to these studies, salinity is considered to be the main driver of ostracod distribution patterns within coastal margin settings in the Mediterranean, and the EGs are as follows: freshwater to low brackish, euryhaline, brackish-marine, and coastal-shallow marine. Notably, the euryhaline group is exclusively represented by *Cyprideis torosa*, the only true euryhaline species able to tolerate salinity conditions ranging from near freshwater to hypersaline (e.g. Frenzel et al., 2010; Berndt et al., 2019 among others).

Further palaeoenvironmental information was derived from observation of the allochthonous ostracod fauna (e.g. poorly preserved, blackish valves), whose

composition is a potential indicator of the main mode of transportation that can be either by rivers or by waves/marine currents within coastal settings.

3.3. Pollen, Non-Pollen Palynomorphs (NPP) and botanical macrofossils

Pollen samples were obtained exclusively from organic clay-rich units due to low pollen concentrations and taphonomic biases in sandy layers. Samples were processed following standard methods (Goeury and Beaulieu, 1979; Girard and Renault-Miskovsky, 1969): treatment with HCl and NaOH, flotation in Thoulet heavy liquid, treatment in HF, and finally mounting in glycerine. 300-400 pollen grains of terrestrial taxa (the pollen sum was lower in some intervals due to low pollen concentrations) were counted using an Olympus Bx43 microscope fitted with $\times 10$ oculars and $\times 40/60$ objectives. Hygrophytic plants (Cyperaceae, *Typha latifolia* and *Typha/Sparganium*) and terrestrial local plants (Chenopodiaceae) were excluded from the pollen sum to avoid over-representation by local taxa. All pollen types are defined according to Reille (1992b) and Cerealia-type was defined according to the morphometric criteria of Faegri and Iversen (1989) (pollen grain $>40\text{ }\mu\text{m}$, pore diameter $>8\text{ }\mu\text{m}$). The identification of Non-pollen palynomorphs (NPPs) followed van Geel (1978, 2001), van Geel et al. (2003), Revelles et al. (2016) and Revelles and Van Geel (2016). Percentage pollen diagrams were created using Tilia software (Grimm, 1991-2011) and pollen zones were defined using stratigraphically constrained cluster analysis (CONISS) (Grimm, 1987).

Pollen analysis was conducted on the following sites, cores and intervals. Saint Florents: 35 samples from different depth intervals (C1: 0.70-0.80 m; C2: 1.25-2.00 m; C3: 2.15-3.00 m; C4: 3.90-4.10 m; C5: 4.30-5.20; C6: 5.30-6.20 m; C7: 6.40-7.30 m). Palo: 26 samples from the depth interval of 0.05-1.90 m. Piantarella 1: 20 samples from the basal section (5.15-6.10 m). Piantarella 2: 9 samples from sections C1 (0.05-0.69 m) and C2 (1.30-1.45 m). Piantarella 3: 28 samples from the basal section (2.50-3.81 m).

Several plant macrofossils were recovered during pollen preparation. Although detailed and specific sampling should be applied for macrofossil analysis, the identification of seed and charcoal provided additional data complementing the pollen analysis results. Macrofossils were transferred to a Petri dish and scanned using a stereoscopic microscope (10–50×). Identifications were made using the standard literature and seed reference collections (Cappers et al., 2006). In the samples containing macroscopic charcoal remains, the identification was carried out by viewing the particles in the three anatomical planes of the wood (transversal, radial longitudinal and tangential longitudinal). The samples were observed with an Olympus BX51 optical microscope and compared with reference samples of modern wood and identification keys published in specialized literature (Schweingruber, 1990).

3.4. RSL reconstruction

The palaeoenvironmental reconstructions reveal facies typical of marine environments, brackish swamps and coastal lagoons (see Section 5.1). Due to the difficulty in defining a direct relationship with the former m.s.l., we used samples deposited within marine facies to produce marine limiting points, which only constrain the RSL position above the elevation of the samples (Vacchi et al., 2016; 2018). We then used samples found in lagoonal facies to produce RSL index points (i.e. a point that constrains the paleo RSL in time and space; e.g. Shennan et al., 2015) following the protocol developed by Vacchi et al. (2016, 2018) and recently applied in several Mediterranean RSL reconstructions (e.g. Fontana et al., 2017; Melis et al., 2018; Brisset et al., 2018). This methodology combines lithostratigraphy and faunal assemblages to define the indicative range (i.e. the relationship of the dated facies with the contemporary m.s.l.; Shennan et al., 2015), an essential parameter for producing RSL index points. Following Vacchi et al. (2016; 2018), we attributed an indicative range of 0 to –1 m m.s.l. to samples from

semi-enclosed lagoonal facies (macrofossil taxa dominated by brackish-water molluscs typical of sheltered marine-lacustrine environments and ostracod assemblages dominated by brackish littoral taxa or inner estuarine taxa). We attributed an indicative range of ± 0.5 m m.s.l. to samples from generally brackish facies (macrofaunal and ostracod assemblages dominated by freshwater to slightly brackish or swamp taxa and shallow marine taxa).

The new RSL dataset was combined with the previously available sea-level data for Corsica (Vacchi et al., 2018).

4. Results

A detailed bio-stratigraphic analysis of the five cores from Piantarella, Saint Florent and Palo enabled several lithological units representing various depositional environments to be distinguished, indicated by the numbers I-V. The radiocarbon dating yielded the following ages for lithological units: Piantarella: ~ 7.4 and 0.4 cal kyr BP (Figure 2, Table 3); Saint Florent: 6.3 cal kyr BP to the present; and Palo: ~ 2.0 to 1.8 cal kyr BP (Figure 2, Table 3). This chronological framework allows us to reconstruct the vegetation history and human-environment interactions since the early Neolithic (i.e. last eight millennia; Figure 2).

4.1. Bio-sedimentary analysis

4.1.1. Piantarella sequence

Piantarella core 1

The core reached granitic bedrock at the depth of 6.20 m. Five main bio-sedimentary units can be distinguished which are described below (Figs. 3A, 4).

- Unit I (6.20-5.15 m; 7425-7197 cal yr BP): grey clays rich in organic matter (5-18%) in which *Posidonia oceanica* remains are abundant. Large specimens of the typical lagoonal bivalve *Cerastoderma glaucum* were found within. The unit contains a rather abundant autochthonous ostracod fauna (~60-350 valves/g) showing an upward increasing trend (Fig. 4). The assemblage is dominated by brackish-marine species (55-75%), with secondary shallow marine-coastal species (20-32%) and the rare (<12%, frequently <5%) but persistent occurrence of the euryhaline species *C. torosa*. *Loxoconcha* species typical of lagoonal/estuarine settings (*L. elliptica* and *L. stellifera*; Montenegro and Pugliese 1995; Ruiz et al. 2000, 2005) and the epiphytic *Xestoleberis* species (mainly *X. dispar*) are the most abundant taxa of the brackish-marine group, with percentages greater than 30% and 15%, respectively. Among the shallow marine-coastal species, the epiphytic taxa *Aurila arborescens* and *Loxoconcha* gr. *Exagona* are the most abundant. Based on the foregoing, we infer that Unit I represents shallow marine to lagoonal environments.

- Unit II (5.15-3.00 m; 7197-5780 cal yr BP): medium to coarse gray sands containing layers of *Posidonia oceanica* and shallow marine to lagoonal bivalve species such as *Cerastoderma glaucum* and *Loripes lacteus*. The unit contains rare autochthonous ostracods, except for the uppermost 10-20 cm that contain an unusual ostracod fauna dominated by shallow marine-coastal species (55-63%), mainly represented by *Loxoconcha* gr. *exagona* and *Palmoconcha turbida* (Fig.4). We infer that Unit II represents shallow marine environments.

- Unit III (3.00-1.70 m; 5780-3400 cal yr BP): heterogeneous sediments consisting of coarse sands containing intact shallow marine molluscs (*Loripes lacteus*, *Cerithium* sp., *Bittium reticulatum* and *Cerastoderma glaucum*), alternating with layers of *Posidonia oceanica*. This unit is also characterised by the dominance of the euryhaline ostracod *C.*

torosa (67-84%), mainly accompanied by brackish-marine species such as *L. elliptica* and *L. stellifera*.

- Unit IV (1.70-1.00 m; 3400-1682 cal kyr BP): alternating coarse gray sand layers with the remains of *Posidonia oceanica* (indicated by peaks in organic matter content of 25-30% in Fig. 3A). No shells are recognized in this unit and it is barren of ostracods. We infer that that Unit IV represents open marine environments

- Unit V (1.00-0.00 m; 1682 cal yr BP to the present): greyish white silty clays with a low organic matter content. No shells were found. The grain-size results and mollusc identifications indicate that this unit corresponds to a low energy sedimentary environment likely corresponding to the modern coastal swamps. One sample from the depth of 75 cm contained abundant (245 valves/g) autochthonous ostracods. *C. torosa* (euryhaline EG) and *Heterocypris salina* (freshwater - low brackish EG) mainly comprise the assemblage with relative abundances of ~77% and ~17%, respectively (Fig. 4).

Piantarella core 2

Five bio-sedimentary units are identified (Fig. 3 A) which are described below

- Unit I (3.15-3.00 m): clayey sediments containing the abundant remains of *Posidonia oceanica*. No shells were recognized.

- Unit II (3.00-1.60 m): gray to greyish white fine to medium sands with a generally low organic matter content (<5%). However, numerous layers of *Posidonia oceanica* are intercalated within the greyish white sands. This second unit contains abundant molluscs with a high representation of shallow marine to lagoonal species such as *Loripes lacteus*, *Cerastoderma glaucum* and *Cerithium* sp.). We infer that this unit was deposited in a high-energy open marine to shallow sedimentary environment.

- Unit III (1.60-1.15 m; 4678-3911 cal yr BP): alternating medium to coarse sandy layers with intercalated gray clay layers containing the remains of *Posidonia oceanica* and small intact shells, mainly *Cerithium* sp.

- Unit IV (1.15-0.90 m; 3911-1845 cal yr BP): medium to coarse gray sands with the intact gastropods *Bittium reticulatum* and *Cerithium* sp. We infer that this unit is a high energy sedimentary environment with a return to shallow marine conditions

- Unit V (0.90 m to the surface; 1845 cal yr BP to the present): heterogeneous in composition with gray clayey layers alternating with fine sandy laminae and layers of *Posidonia oceanica*. Molluscs are not abundant, but intact specimens such as *Cerithium* sp. Occur in the sandy intervals (0.10 m dept). The first 10 cm of are exclusively composed of gray clays, corresponding to modern brackish swamps.

Piantarella core 3.

Four sedimentary units are recognized and they are described below (Fig. 3A).

- Unit I (4.20-4.00 m; >6700 cal yr BP): coarse gray sands (mean grain size of ~750 μ m to 1 mm) containing intact specimens of the marine gastropod *Bittium reticulatum*. However, in the upper part of the unit, large specimens of lagoonal bivalves *Cerastoderma glaucum* occur, thus indicating an alteration of the marine to shallow marine conditions. The organic matter content is low (<5 %). The grain-size characteristics indicate a high energy sedimentary environment, possibly an open marine cove.

- Unit II (4.00-2.50 m; 6700-5293 cal yr BP): black organic clays. The organic matter content ranges from 3-18 % and there are four distinct peaks (15-18 %) at the depths of 2.55, 2.70, 3.05 and 3.60 m. Numerous plant remains and large wood fragments were found embedded within the organic clays (mean grain-size ~10 μ m). Molluscs are

scarce and only a few layers of intact and fragments of *Cerastoderma glaucum* occur at the depths of 2.40, 2.65 and 2.90 m.

- Unit III (2.50-0.50 m; 5293-1186 cal yr BP): medium to coarse gray sands (modal size ~1.00-1.250 mm) containing numerous layers of *Posidonia oceanica*. Intact marine gastropods (*Rissoa ventricosa*, *Nassarius reticulatus* and *Bittium reticulatum*) were found within the coarse sandy fraction. We infer that this units represents a high energy open marine to shallow marine environment.

4.1.2. Saint-Florent sequence

Three main bio-sedimentary units can be distinguished and are described below (Figs. 3B, 5):

- Unit I (7.35-2.40 m; 6301-3918 cal yr BP): sandy silts (with oscillating mean grain-size within the range of 15-105 μ m). There are frequent changes in granulometry, with silty clayey layers alternating with silts to fine sands. The coarsest intervals are 7.35-6.60 m and 3.80-2.45 m, in which the mean grain size and modal index vary between 50 μ m and 105 μ m. The organic matter content is generally high (5-15 %) with a peak at ~3.60 m (15%), while at ~4.15 m there is a lower organic matter content (~5 %). The carbonate content is generally within the range of 8-30 %, reaching a peak (30 %) at ~4.15 m while lower values (8-10%) occur between 3.20 and 2.45 m. Notably, within the interval of 2.50-5.70 m deep, there are molluscs indicative of marine to shallow marine conditions such as *Loripes lacteus*, *Cerastoderma glaucum*, *Cerithium* sp. and *Rissoa ventricosa*. Within the interval of 5.70-7.35 m, no intact shells were found and only small fragments were are recognized. Within the interval of 1.40-7.35 m, *Posidonia oceanica* remains are abundant, mixed with sandy deposits.

The interval of 7.25-4.20 m contained an abundant autochthonous ostracod fauna (commonly ~300-900 valves/g) (Fig. 5). Uniquely, the sample from 475 cm, which contains a small number of valves (20 valves within the entire >125 µm fraction), and the sample from 705 cm were barren of ostracods. The ostracod fauna is mainly composed of brackish-marine (30-70%) and shallow marine-coastal (25-60%) species, with rare (<10%, often <5%) and the occasional occurrence of the euryhaline species *C. torosa*. Within the brackish-marine group, the opportunist *Leptocythere lagunae* is the dominant species along with the epiphytic taxa *Cytherois fischeri* and *Xestoleberis* spp. *Loxoconcha* spp., mainly *Loxoconcha* gr. *exagona* and *L. rhomboidea*, and *Carinocythereis whitei* are the main taxa comprising the shallow marine-coastal group. The euryhaline species *C. torosa* is continuously present within the interval 575-420 cm (5466-4922 cal yr BP), along with an increase in the percentages of *Leptocythere lagunae* and *Loxoconcha elliptica* (Fig. 5 and Table S2), species typical of lagoonal/estuarine settings (Montenegro and Pugliese 1995; Ruiz et al. 2000,2005; Nachite et al. 2010)

The overlying interval, 420-240 cm, contains few valves of well-preserved ostracods, mainly represented by *C. torosa*, *L. lagunae*, *Xestoleberis communis* and the *L. exagona* group.

- Unit II (2.40-0.50 m; 3918 cal yr BP to the present): dark gray clays (mean grain size of ~5 µm). There are strong oscillations of the mean grain size within this unit and only the modal index exhibits a minor oscillation at ~1.30 m depth, with values of ~25-30 µm. The organic matter content is high (12-50 %) in the lower part with a peak at 2.40 m (50 %), but in general the values are within the range of 10-18 %). The remains of *Posidonia oceanica* occur within the interval of 1.40-2.48 m. The carbonate content is uniform, generally within the range of 8-10 %. The molluscs are the typical lagoonal

bivalve *Cerastoderma glaucum* (1.40-2.48 m). No shell remains were found in the interval from 1.40 m to the surface.

A rather abundant (~75-140 valves/g) oligotypic ostracod fauna exclusively composed of the euryhaline species *C. torosa* characterizes the lowermost portion of this unit, while the uppermost interval (2-0.50 m) is barren of ostracods (Fig. 5).

- Unit III (0.50 m to the surface; present): heterogeneous material with intercalated clayey layers within a sandy matrix. The upper part contains black organic clays, corresponding to the modern coastal swamps. No molluscs and ostracods were identified.

4.1.3. Palo sequence

Four main sedimentary units were identified based on granulometric measurements and they are described below (Fig. 3C).

- Unit I (3.15-1.70 m; >2900-2746 cal yr BP): predominantly medium to coarse gray sands.

- Unit II (1.70-1.50 m; 2746-2550 cal yr BP): gray clays with a low organic matter content.

- Unit III (1.50-1.00 m; 2550-1931 cal yr BP): medium to coarse gray sands.

- Unit IV (1.00 m to the surface; 1931 cal yr BP to the present): gray clays with thin organic matter layers within the lower part and traces of oxidation (roots) in the upper part.

Throughout the entire sequence, only minor amounts of fine shell debris were encountered, preventing their reliable identification.

533

534 **4.2. Pollen and NPP analysis and plant macrofossils**

535 **4.2.1. Saint-Florent core**

536 Two main pollen zones and four sub-zones were defined using stratigraphically
537 constrained cluster analysis (CONISS) (Grimm, 1987) and together with the NPP they
538 are described below (Figs. 6A and 6B).

539 - Sub-zone A1 (5.30-7.30 m; 6301-5224 cal yr BP): There is an increasing trend of AP
540 values (47-70%), dominated by *Quercus ilex-coccifera*, *Alnus* cf. *glutinosa*, *A.* cf.
541 *suaveolens*, *Pinus* and *Erica* (Fig. 6A). The first occurrences of Cerealia-type is at 5.30,
542 5.70, 6.40 and 6.50 m. High values of fern spores occur, together with the highest and
543 continuous values of *Isoetes* (Fig. 6B). Spores of carbonicolous/lignicolous and
544 coprophilous fungi are present, and there is an almost continuous curve of *Spirogyra*
545 and *Pseudoschizaea* and the occurrence of Foraminifera.

546 - Sub-zone A2 (2.50-5.20 m; 5180-4209 cal yr BP): The AP values remain stable or are
547 slightly higher (57-82%), while there are decreases in *Quercus ilex-coccifera* and
548 deciduous *Quercus*. An expansion of riparian trees occurred in this sub-zone, mainly
549 *Alnus* cf. *glutinosa* and *Alnus* cf. *suaveolens* (Fig.6A). Cerealia-type is present at the
550 depths of 3.90, 4.70, 4.90, 5.00 m. There is a decreasing trend of *Isoetes*, fern spores
551 and *Pseudoschizaea*, and low values of freshwater algae (Fig. 6B).

552 - Sub-zone B1 (1.45-2.40 m; 3918-843 cal yr BP): There are increases in *Quercus ilex-*
553 *coccifera*; decreases in *Pinus*, *Alnus* cf. *glutinosa*, *A.* cf. *suaveolens* and *Erica*; and a
554 remarkable increase in Poaceae and Chenopodiaceae. Sharp decreases in *Q. ilex-*
555 *coccifera* and AP values occur above 1.50 m (~50 cal yr BP), followed by an increase in

Poaceae and the occurrence of Cerealia-type (Fig. 6A). There is a decrease in fern spores, the sporadic occurrence of freshwater algae and *Pseudoschizaea*, and the occurrence of coprophilous fungi at 1.55 m depth (~1000 cal yr BP) (Fig. 6B).

- Sub-zone B2 (0.70-1.35 m; 686-20 cal yr BP): There is a sharp decrease in AP values (reaching a minimum of 20%), mainly caused by decreases in *Alnus* and *Quercus ilex-coccifera* (Fig. 6A), and a large increase in Poaceae together with high values of *Rumex*, Brassicaceae, *Plantago*, *Artemisia*, *Aster*-type and Apiaceae. There is the combined occurrence of Cerealia-type with high values of coprophilous fungi in this zone. Peaks in fern spores and in the pollen of aquatic and hygrophilous plants occur during 1000-500 cal yr BP (Fig. 6B).

4.2.2. Palo

Two main pollen zones and four sub-zones are defined using CONISS (Grimm, 1987) and the NPP are described in the context of the pollen zones (Figs. 7A and 7B).

- Subzone A1 (1.45-1.90 m; 2876-2496 cal yr BP): There are very high AP values (66-86 %), dominated by *Alnus*, *Quercus ilex-coccifera* and *Pinus* (Fig. 7A); in addition, there are low values of *Quercus deciduous*, high values of *Erica* (showing a decreasing trend at the end of the sub-zone), and low values of Poaceae, Asteraceae and Chenopodiaceae. Coprophilous fungal spores are present and there are low values of aquatic and hygrophytic plants, and the absence of algae and *Pseudoschizaea* (Fig. 7B).

- Subzone A2 (0.80-1.00 m; 1931-1678 cal yr BP): There is a slight decrease in AP caused by a reduction of *Alnus* (Fig. 7A) and a sharp increase in Poaceae, linked with the presence of Cerealia-type (0.80 m, 1678 cal yr BP). There are high values of Chenopodiaceae and increases in aquatic and hygrophytic plants.

- Subzone B1 (0.25-0.75 m; 1600-565 cal yr BP): There is a decrease in AP (mainly *Alnus*, *Pinus* and *Q. ilex-coccifera*) but peaks in *Quercus* deciduous (Fig. 7A). *Erica* increases and there is a decrease in Poaceae values and a large increase in Asteraceae (especially *A. liguliflorae*). Chenopodiaceae decreases and is absent in some samples, and there is the continuous representation of *Pseudoschizaea* and sporadic peaks in aquatic and hygrophytic plants, freshwater algae, *Isoetes* and other ferns (Fig. 7B).

- Subzone B2 (0.05-0.20 m; 445-75 cal yr BP): There are low values of AP due to decreases in *Pinus* and *Alnus* and the expansion of Poaceae, Asteraceae and *Plantago lanceolata* (Fig. 7A). Cerealia-type is present at 0.05-0.10 m (199-75 cal yr BP) and there are high values of the spores of coprophilous fungi (Fig. 7B) There are also high values of Chenopodiaceae and a decreasing trend of aquatic and hygrophytes, algae and ferns.

4.2.3. Piantarella I

Two pollen zones are defined (Figs. 8A and 8B).

- Zone A (5.65-6.10 m; 7406-7317 cal yr BP): There are low values of AP (~ 10-25%), and *Quercus* deciduous and *Quercus ilex-coccifera*; and there are very low values of *Alnus* cf. *glutinosa* and *A. cf. suaveolens*. The AP is dominated by *Pinus*. The highest values of *Erica* occur and there is a continuous curve of Cistaceae, an increasing trend of Poaceae, and high values of Asteraceae liguliflorae (peaks of ~18%). ~~but showing a decreasing trend (0.3% at 7348 and 3.4% at 7317 cal-yr BP).~~ There are high values of Chenopodiaceae, with an increasing trend, from 22-45% to 50-81% (Fig. 8A). Cerealia-type is continuously present at the end of the zone (5.65-5.90 cm, 7368-7317 cal yr BP). There is also an increasing trend of *Isoetes* and high values of other ferns (Fig. 8B).

Peaks in freshwater algae, *Pseudoschizaea*, *Isoetes* and other ferns occur at 5.65-5.80 cm (~7348-7317 cal yr BP), coinciding with a peak in Chenopodiaceae.

- Zone B (5.15-5.60 m; 7307-7197 cal yr BP): There is a decrease in *Erica* and the expansion of herbs, mainly *A. liguliflorae*, Poaceae and *A. tubuliflorae* (Fig. 8A). Cerealia-type is continuously present at 5.30-5.50 m (7284-7237 cal yr BP). There is a decreasing trend in Chenopodiaceae, uniform representation of aquatic and hygrophilous plants and the expansion of *Isoetes* (Fig. 8B).

4.2.4. Piantarella 2

Two main pollen zones are defined (Figs. 8A and 8B).

- Zone A (1.30-1.45 m; 4668-4659 cal yr BP): There are high value of AP (29-48%), dominated by *Quercus ilex-coccifera* and *Pinus*. The landscape was dominated by scrubland, with *Erica* and Cistaceae (Fig. 8A and 8B) and with a high representation of Chenopodiaceae. There are low values of freshwater algae, *Pseudoschizaea*, aquatic and hygrophilous plants, *Isoetes* and other pteridophytes, and carbonicolous-lignicolous and coprophilous fungi and foraminifera are present (Fig. 8B).

- Zone B (0.05-0.69 m; 414 cal yr BP- modern): There are decreases in AP and *Q. ilex-coccifera* (Fig. 8A), peaks in Poaceae and *A. liguliflorae* at 0.53 m and a peak in *Erica* at the top of the zone. In addition, there are high values of Chenopodiaceae and aquatic and hygrophyte taxa and ferns are poorly represented (Fig. 8B).

4.2.5. Piantarella 3

Two pollen zones are defined (Figs. 8A and 8B).

- Zone A (3.58-3.81 m; 6615-6426 cal yr BP): There are low values of AP (~20%) at the beginning of the zone, but with subsequent increases (26-36%). There is the similar

representation of *Quercus* deciduous and *Quercus ilex-coccifera*, and very low values of *Olea* but with a large increase after ~6500 cal yr BP (Fig. 8A). There are high values of Asteraceae liguliflorae, A. tubuliflorae, *Cirsium*-type and low values of Chenopodiaceae. Cerealia-type is present at the depths of 3.58, 3.63-3.66 and 3.77-3.81 m. There are high values of Cyperaceae, *Isoetes* (with a short regression at 3.77 m) and other ferns and freshwater algae (Fig. 8B). Coprophilous fungal spores are present at 3.60 m.

- Zone B (2.50-2.97 m; 5881-5293 cal yr BP): There is a slight decrease in AP values, mainly *Quercus* deciduous, *Corylus* and *Olea* at 2.85-2.97 m (5881-5749 cal yr BP), and increases in *Erica* and Cistaceae. Cerealia-type is absent. An increase in AP occurs after 5749 cal yr BP, with the highest values of *Olea*, a slight increase in *Pinus* and *Corylus* and a decrease in *Quercus* deciduous. There is an increase in *Erica* and the continuous representation of Cerealia-type within the interval of 2.58-2.72 m, and a slight increase in Chenopodiaceae. At the end of the zone (2.50-2.54 m; 5350-5293 cal yr BP), there is a decrease in AP values (*Quercus* deciduous, *Corylus*, *Quercus ilex-coccifera*, *Olea*, *Pistacia* and *Tamarix*), and the expansion of *Erica* and Cistaceae, with the occurrence of Cerealia-type and increases in *Cirsium*-type and *Asphodelus* (Fig. 8A). A slight increase in the representation of salt-tolerant plants occurs in this zone, together with decreases in aquatic and hygrophYTE plants, freshwater algae and ferns (Fig. 8B). Notably, the occurrence of the spores of coprophilous fungi coincides with the continuous representation of Cerealia-type.

4.2.6. Plant macrofossils

While charcoal was present in most of the Saint Florent and Piantarella samples, few samples contained charcoals large enough to identify (Table 5).

4.3. *RSL datapoints*

Bio-stratigraphic analysis and the resulting palaeoenvironmental reconstructions (see sections 4.1 and 5.1) enable the production of a new set of ten RSL index points as well as eight marine RSL limiting points.

Seven new RSL index points were produced for samples from the lagoonal unit (five at Piantarella and two at Saint Florent) and three RSL index points from samples found in a brackish swamp unit (all from Piantarella, Table 4). The eight new marine limiting points (five at Piantarella and three at Saint Florent) were produced for samples from shallow and full marine units (Fig. 9, Table 4). The lack of a well-defined faunal content in the Palo samples (section 4.1.3) prevented the extraction of sea-level data from this core.

This new dataset significantly improves the RSL record for Corsica (Fig. 9 A,B), notably in the southern sector. In northern Corsica (Fig. 9A), the oldest limiting point places the RSL above -7 m at ~6.3 cal kyr BP, while the oldest index point indicates that the total RSL variation at ~4.2 cal kyr BP was 1.6 ± 0.6 m, in good agreement with the previously available RSL index points. In Saint Florent, the oldest limiting point constrains the RSL above -6 m at ~7.4 cal kyr BP. A suite of mid-Holocene index points indicates that RSL rose from -3.3 ± 0.6 m at ~6.6 cal kyr BP to -2.1 ± 0.6 m at ~5.5 cal kyr BP. The younger datapoints document a significant reduction in the rate of rise rates with an entire range of RSL variation that did not exceed ~1.5 m since ~4.6 cal kyr BP.

5. Discussion

5.1. *Palaeoenvironmental evolution of the coast of Corsica during the Middle and Late Holocene.*

The multi-proxy study of the Saint Florent, Palo and Piantarella cores enables us to reconstruct the main stages of the evolution of the Corsican coastal landscape since the mid-Holocene. The analysis below highlights the bio-sedimentary and palaeoecological dynamics in different coastal areas of Corsica.

5.1.1. Mid-Holocene

The Piantarella 1 cored succession, in the southern part of Corsica, provides the oldest data for reconstructing the Mid-Holocene coastal palaeoenvironment (Figs. 3A, 4). The first stratigraphic evidence of a marine transgression is the abrupt superposition, above the bedrock (granite), of deposits containing a mixed brackish-shallow marine macro and meiofauna, dated to ~7.4 cal kyr BP (early Neolithic; Fig. 4). The co-occurrence of the euryhaline *C. torosa*, although at low percentages, points to a protected bay environment with a muddy-sandy substrate with a dense vegetation cover, as testified by epiphytic species (i.e. *X. dispar*, *A. arborescens* and *Loxoconcha* gr. *exagona*). The very high representation of *Loxoconcha* species typical of semi-enclosed coastal settings (*L. elliptica* and *L. stellifera*) supports this interpretation, as does the presence of large intact specimens of the lagoonal bivalve *C. glaucum* and the evidence of the local presence of saltmarshes, hygrophytic plants and riparian trees in the pollen record (Fig. 8A). In this context, it appears that the pre-existing freshwater pools (prior to ~7.4 cal yr BP) were transformed to brackish environments as a result of salt intrusion caused by the continuous sea level rise. The pollen and NPP results (Fig. 8B) demonstrate the importance of pteridophytes at the local scale, mainly *Isoetes*, but also other ferns. High values of the salt intolerant *Isoetes* within the entire sequence, as well as a continuous curve of *Pseudoschizaea* and the occurrence of freshwater algae, point to the resilience of freshwater organisms against sea level rise and the increasing salinity during the Early Neolithic. Nevertheless, the influx of sea water is evidenced by

the occurrence and peaks of foraminifera and the high values of salt-tolerant plants, mainly Chenopodiaceae (Fig. 8A).

At ~7.0 cal kyr BP (i.e. at the transition from the early to middle Neolithic) a high-energy marine environment developed, characterised by medium to coarse gray sands rich in marine molluscs and a transported marine-brackish ostracod fauna. This sequence passes upwards into an autochthonous assemblage dominated by shallow marine species (Fig. 4). This peak in shallow marine ostracods likely marks the maximum marine transgression in the area at ~5.9 cal kyr BP, consistent with the dating of the same phenomenon in NE Sardinia at ~6.0 cal kyr BP (Melis et al., 2018). The presence of shallow-marine sandy deposits at Piantarella 1 may point to the formation of a coastal barrier that determined the development of the lagoon system at the transition from transgressive to regressive conditions (Fig. 9). Accordingly, lagoon deposits first occurred in the northern portion (Piantarella 3) at ~6.8 cal kyr BP and then occupied the entire area from north to south.

The pollen and NPP record of Piantarella 3 demonstrates the predominance of freshwater indicators during the intervals of 6615-6426 and 5881-5293 cal yr BP. High values of *Isoetes* along the whole sequence, as well as continuous curves of *Spirogyra* and *Pseudoschizaea*, since Early Neolithic, reinforced by the regression of Chenopodiaceae (Fig. 8A), point to the consolidation of a low brackish lagoon and low marine influence during the Middle and Late Neolithic. This is consistent with the progressive isolation of the area by the development of the coastal barrier, as attested in Piantarella 1; in addition, the pollen data suggest the prevalence of a slightly brackish environment, with higher values of hygrophytic plants as opposed to salt-tolerant plants (Fig. 8B).

A distinctive change in ostracod fauna, marked by the abrupt increase in *C. torosa*, records the establishment of a lagoonal/shallow marine setting at Piantarella 1 at ~5.7 cal kyr BP and then to the south at Piantarella 2 (Fig. 3A). These conditions persisted until the onset of the Late Holocene (~4.3 cal kyr BP), even though a progressive increase in the degree of isolation is marked by the upward decreasing trend in coastal-shallow marine, and to a lesser extent brackish-marine taxa at Piantarella 1 (Fig. 4).

In contrast to the Piantarella site, there is no evidence of the development of a lagoonal system in the northern part of Corsica, at Saint Florent. At this site, a protected bay characterized by dense riparian vegetation at the base and muddy-sandy substrates persisted throughout the Middle Holocene (6274-4985 cal yr BP), as documented by the faunal content which is characterised by mixed brackish-shallow marine ostracods with the sporadic occurrence of *C. torosa* (Fig. 5). Moreover, since ~5.5 cal kyr BP, an increase in fluvial influence (and perhaps also in the degree of isolation) is attested by the persistent occurrence of the euryhaline *C. torosa* and an increase in the relative abundance of opportunistic species such as *L. elliptica* and *L. lagunae* (Fig. 5). This interpretation is supported by the appearance of rare freshwater – low brackish species (*Candona* spp. and *P. albicans*). The pollen results indicate the existence of local alder carr environments, consistent with the major expansion of alder-dominated forest in several floodplains of the central Mediterranean region during ~6.0-5.0 cal kyr BP (Magri et al., 2019). High values of fern spores and a continuous curve of freshwater algae document the existence of permanent freshwater at the local scale and the occurrence of foraminifera during this phase, indicate a connection with the sea. Nevertheless, the riparian forest remained resilient during this period and saline-tolerant plants are poorly represented (Fig. 6B).

At ~5.0 cal kyr BP, the transition to a beach environment is indicated by the occurrence of a sparse, poorly-preserved ostracod fauna (mainly brackish-marine and shallow marine - coastal species) within a sandy succession, pointing to a shallowing-upward trend that reflects coastline progradation during the last interval of the Middle Holocene (~5.0-4.0 cal kyr BP). The occasional occurrence of freshwater – low brackish indicators (e.g. poorly-preserved specimens of *Candona* and *Characeae* oogons) suggests some degree of fluvial influence (possible the Aliso palaeo-river) in the coastal-marine setting.

5.1.2. Middle-Late Holocene transition: the ~4.2 ka event in Corsica

The new dataset indicates that the period of ~4.5-4.0 cal kyr BP was a phase of major environmental change along the coast of Corsica. This is likely due to the high amplitude climatic oscillations at this time (Magny et al., 2012, 2013) and the concomitant RSL stabilisation (Vacchi et al., 2016; 2018, Fig. 9). During this period, the lagoon was infilling with sediments transported under high energy conditions by storms in Piantarella (South Corsica; Fig. 1), a brackish wetland developed in Saint Florent (North Corsica, Fig. 1), and there was a transition from an open to a semi-enclosed lagoon in Aleria del Sale (Eastern Corsica, Currás et al., 2017). These major shifts in the coastal landscape configuration in the mid- to late-Holocene transition were likely linked with the ~4.2 ka event (Bond et al., 1997; Bini et al., 2019), as previously suggested for Eastern Corsica (Currás et al., 2017). Intense overwash deposition inside Piantarella lagoon is consistent with increased storm activity recorded during the 4.2 ka event and documented in several other western Mediterranean lagoons (Sabatier et al., 2012; Kaniewski et al., 2016; Marriner et al., 2017; Bini et al. 2019). In addition, the fluvially-influenced coastal setting at the Saint Florent site appears to have been affected by a marked progradational trend linked to an increase in fluvial activity, as

recorded in other western Mediterranean areas such as the Arno coastal plain (Rossi et al., 2012; Sarti et al., 2015) and NE Sardinia (Melis et al., 2018).

However, our data indicate that this climatic event did not have a major impact on the regional vegetation. This is consistent with other Corsican pollen records (Reille, 1992; Reille et al., 1999; Poher et al., 2017; Currás et al., 2017) which also indicate that the 4.2 ka did not significantly affect the vegetation of Corsica (Di Rita and Magri, 2019). This cooling event have had an influence only at a local scale, resulting in local reductions in riparian forest at Saint-Florent (Fig. 6B) and Piantarella (Fig. 8B). Finally, the combination of increasing salinity and aridity, in the context of the 4.2 ka event, may have triggered the local expansion of Chenopodiaceae (Fig. 8A), a reliable indicator of salt-marsh occurrence in Mediterranean coastal contexts (Court-Picon et al., 2010; Di Rita et al., 2011; Di Rita and Melis, 2013; Burjachs et al., 2017; Revelles et al., 2018).

5.1.3. Late Holocene

While environmental local changes during the mid-Holocene were mainly the result of changes in the rates of RSL, climatic fluctuations and the trend towards increasing aridity have probably also determined the nature of major coastal changes in the Late Holocene. Since ~4.3 cal kyr BP, we observe the progressive silting of the Piantarella lagoon, and at ~1.6 cal kyr BP it was transformed to brackish swamps colonized by a euryhaline ostracod fauna and dominated by Chenopodiaceae marshland (Fig. 8A). The pollen record demonstrates that freshwater indicators are almost absent and the high values of Chenopodiaceae suggest high salinity levels from ~4.5 cal kyr BP onwards. The current marshlands started to form during ~0.8-0.4 cal kyr BP (Fig. 3A), indicating higher salinity levels (Piantarella 2, Fig. 8B).

At Saint Florent, we observe a transition from a beach environment to a brackish lagoon/wetland, as indicated by the occurrence of an oligotypic euryhaline ostracod fauna (*C. torosa*) and Chenopodiaceae and Poaceae marshland, and finally to modern swampland. The formation of modern marshland started at ~1.6 cal kyr BP (Fig. 3B). However, high Chenopodiaceae values and the concomitant decreases in algae, fern spores and especially *Alnus* cf. *glutinosa* and *A.* cf. *suaveolens*, suggest an increase in salinity since the development of lagoonal phases at ~4.0 cal kyr BP. The expansion of Chenopodiaceae during ~4.5-4.0 cal kyr BP is documented in other records along both the northern (Saleccia, Reille, 1992a) and the southern coast (Poher et al., 2017) of Corsica. This may be related not only to higher salinity conditions, but also to a trend towards a drier climate. Thus, peaks in the pollen representation of salt-tolerant plants (mainly Chenopodiaceae) during the Late Holocene at Saint Florent are likely related to cooling events as well as to phases of increasing aridity, as is the case for the global cooling events at ~3.2-2.8, ~1.4, and ~0.5 cal kyr BP (Fig. 6B). The peak in salt-tolerant plants during ~3.2-2.8 cal kyr BP may be linked to a marine incursion probably related to a period of increasing storms which frequently flooded the coastal lagoons, as documented in the Sagone Valley (Western Corsica) during ~3.3-3.1 cal kyr BP (Ghilardi et al., 2017).

At Palo (Eastern Corsica), a marine environment occurred at the beginning of the Late Holocene, followed by a phase of brackish swamps with the spread of alder forest (Fig. 7B) during ~2.8-2.5 cal kyr BP (Fig. 3C). A marine environment is documented during ~2.5-1.9 cal kyr BP, after which a brackish environment with elements of alder forest communities and salt-resistant Chenopodiaceae occurred, indicating a partial re-establishment of swampland in this area of the Eastern Coastal Plain under a higher salinity influence. This succession of marine and brackish environmental conditions is

indicated by the increase of salinity indicators during ~2.5~1.9 cal kyr BP (Fig. 7B), a decrease during ~1.5-0.5 cal kyr BP, and a further increase during modern times.

5.2. Vegetation history and climate change since the Middle Holocene in Corsica.

Local reconstructions and regional differences.

As stated in the introduction, one of the main unresolved issues regarding the vegetation history of Corsica is the status of the landscape prior to human occupation. The dominance of *Erica* (identified as *Erica arborea*) in low and moderate altitude pollen records raises the question whether *Erica* formed scrubland, and thus that the vegetation was open since the early Holocene, or if it formed forests as suggested by Reille (1992a) and Reille et al. (1999) and which is supported by the palaeoentomological study of Poher et al. (2017). The present study provides new insights into this issue, as in both the Saint-Florent and Piantarella records *Erica* shows high values from the start of the sequence (~7.4 cal kyr BP in Piantarella 1, Fig. 8A; ~6.3 cal kyr BP at Saint Florent, Fig. 6A). Comparatively, the pollen record from Saint Florent (North Corsica) suggests a denser vegetation, dominated by sclerophyllous forest at the regional scale and riparian forest at the local scale (Fig. 6B). In this context, the high values of *Erica* are likely related to Mediterranean scrubland growing on drier soils or at lower elevations in the context of the predominance of evergreen oak forest at the regional scale (and riparian forest at the local scale, Fig. 6A and 6B). Nevertheless, the age of the base of the Saint-Florent sequence (~6.3 cal kyr BP) could be post-dates to the *E. arborea* to *Q. ilex* forest succession described for the Atlantic period by Reille (1975, 1984, 1992a).

In the case of the Piantarella records (Southern Corsica), *Erica* was dominant in the landscape from ~7.4 cal kyr BP to the present (maximum of 64% at ~7.4 cal kyr BP), with phases of regression (during 7.3-7.2 cal kyr BP in Piantarella 1, and during 6.6-6.4

cal kyr BP in Piantarella 3, Fig. 8A). However, it was never exceeded by sclerophyllous forest (which increased slightly from ~6.5 cal kyr BP onwards, Fig. 8B). Following the interpretation of M. Reille, maximum values of *Erica* at Piantarella during ~7.4-7.3 cal kyr BP would have been indicative of former *Erica arborea* forest that was progressively affected by human impacts, resulting in its conversion into Mediterranean scrubland (Reille, 1984, 1988a, 1998b, 1992a). Nevertheless, the identification of a seed of *Erica scoparia* at 250 cm (5293 cal kyr BP) in Piantarella 3 suggests the possibility that the *Erica* pollen signal consists of a mixture of different *Erica* species other than *Erica arborea* (*E. scoparia*, *E. multiflora* and *E. cinerea* are also found today in Corsica). These species are more characteristic of scrubland and do not form forest. Irrespective of whether or not *Erica arborea* forest existed during the Early Holocene, maquis vegetation dominated by *Erica* would have existed since the mid-Holocene in southern Corsica, probably as a result of human impacts since the early Neolithic. Furthermore, high values of Cistaceae and Asteraceae suggest the existence of low scrubland and pasture within heath-dominated vegetation (Fig. 8A). In addition, the evidence of *Erica* sp. and *Arbutus unedo* macroscopic charcoal (Fig. 8B, Table 5) points to frequent fire episodes affecting the maquis during the mid-Holocene, which would have prevented the growth of *Erica* and the formation of forest.

The expansion of *Quercus ilex-coccifera* forest during ~7.0-5.5 cal kyr BP is proposed as a consequence of the degradation of the original *Erica* woodland by Neolithic communities in Corsica (Reille 1975, 1984, 1992a). The expansion of evergreen *Quercus* is also documented in Sicily during the Middle Holocene (Calò et al., 2012, Noti et al., 2009, Tinner et al., 2009) and in Malta (Djamali et al., 2013, Gambin et al., 2016). In some cases, as in coastal areas of the Italian Peninsula (di Rita et al., 2015), the expansion of *Quercus ilex-coccifera* during ~9.0-8.0 cal kyr BP suggests a degree of

diachronism in the regional expansion of evergreen oak vegetation which may be related to site-specific ecological dynamics involving tree populations within coastal refugia, in a period characterized by minimal human impact.

In this context, the *Erica* - *Quercus ilex-coccifera* succession in Corsica has been proposed as the result of the decrease in summer insolation leading to drier winters and moister summers north of 40°N, and a decrease in fire frequency, thus favouring *Quercus ilex-coccifera* as opposed to *Erica* (Beffa et al., 2016). The reduction of mesic vegetation is documented at Piantarella and Saint Florent after ~5.3 cal kyr BP, probably linked with a cold phase in the Gulf of Lion during ~5.3-5.0 cal kyr BP (CR2, Jalali et al., 2016) and the cold event ascribed to ~5.3-4.7 cal kyr BP (Frigola et al., 2017) in the Balearic Sea. In northern Corsica, the increase of *Quercus ilex-coccifera* occurs at ~6.4 cal kyr BP (Saleccia) and at ~6.5 cal kyr BP (Fango) (Reille, 1992a). At Saint Florent, this process of expansion cannot be addressed because *Quercus ilex-coccifera* has high values from the start of the sequence (6.3 cal kyr BP), a regression phase occurs during ~5.2-4.2 cal kyr BP, and highest values occur during ~4.0-0.9 cal kyr BP (Fig. 6A). This phenomenon is not observed at Piantarella (South Corsica), where only a slight increase in *Quercus ilex-coccifera* occurs at ~4.5 cal kyr BP (Piantarella 2, Fig. 8A), consistent with data from Cavallo Island (Poher et al., 2017). The low values of *Quercus* sp. documented in southern Corsica could be interpreted as a long-distance signal from higher elevations, and that mesic and sclerophyllous forests did not exist at a local scale.

Other notable feature in the vegetation history of Corsica ~~history~~ during the Mid-Late Holocene transition is the expansion of *Fagus*, which is continuously represented with highest values after ~4.5 cal kyr BP at St. Florent (Fig. 6A) and Piantarella (Fig. 8A). This is consistent with the results of previous studies in South Corsica, in both mountain

areas (Massif du Monte Incudine; Reille, 1975, Reille et al., 1999) and along the coast (Poher et al., 2017).

Considering that after the first Neolithic impact and the role of fire, the pollen representation of *Erica* would mainly reflect the existence of scrubland in the landscape, this study shows that AP values are clearly different in North and South Corsica since the Middle Holocene. At Saint Florent, the range of AP values during 6301-5224 cal kyr BP is 59-74%, with a maximum 80% and minimum of 47%; in Piantarella, the range of AP values is 17-27% during 7406-7197 cal yr BP; 13-32% during 6615-5293 cal yr BP, with a maximum of 36% and a minimum of 7% (Figs. 6A, 8A). This demonstrates differences in forest density, with relatively dense forest in North Corsica and open vegetation in South Corsica since the Middle Holocene. Surprisingly, the AP values in Piantarella 2 indicate an expansion of forest (28-48% AP) (~4.5 cal kyr BP), mainly as a result of increases in *Quercus ilex-coccifera* and *Pinus* at the expense of grassland (Figs. 8A and 8B). This suggests low human impact during the Chalcolithic in southern Corsica, different from the anthropogenic impact documented at St. Florent (Figs. 6A and 6B) and in eastern Corsica (Currás et al., 2017) during this period. Vegetation as open as that documented at Piantarella is not evident at Saint Florent until the Middle Ages, as a result of human impact. Thus, in North Corsica the existence of open vegetation was a result of human impacts in historical times, with evergreen sclerophyllous forest being the main vegetation component. In South Corsica, open vegetation dominated by Mediterranean maquis has existed since the Middle Holocene and human impact is often expressed as a reduction of scrubland, as in the Early and Middle Neolithic (Fig. 8A and 8B). In the case of Palo (Figs. 7A and 7B), high AP values are documented during ~2.9-2.5 cal kyr BP, demonstrating the resilience of the mesic vegetation and being consistent with previous data from the region (Reille, 1984,

Currás et al., 2017). Increasingly open vegetation with the expansion of grasslands developed from Roman times onwards as a result of further human impacts (Fig. 7B). This feature is documented by the stronger anthropogenic signal from ~2.6 cal kyr BP onwards in previous studies in Corsica (Reille, 1975, 1984) and in Mediterranean coastal ecosystems in general (Di Rita and Magri, 2012). The decline of *Quercus ilex-coccifera*. and *Alnus* and the increase in Poaceae and Asteraceae since ~1.7 cal kyr BP at Palo coincides with similar trends at the northern site of Aleria del Sale (Eastern Corsica; Currás et al., 2017). During the Middle Ages (~1.4-0.7 cal kyr BP, 6th-13th centuries), the regression of evergreen oak and the spread of *Erica* indicate the establishment of a more open landscape. At the same time, local marshlands characterised by Chenopodiaceae were progressively replaced by Asteraceae species, indicating local environmental changes with the occurrence of freshwater conditions (Fig. 7B).

5.3. Influence of Neolithic occupation on the coastal landscape of Corsica

5.3.1. Early Neolithic (~7.8-6.8 cal kyr BP)

The results from Piantarella 1, spanning the interval of ~7.4-7.2 cal kyr BP, are the oldest record of the Early Neolithic recovered so far along the Corsican coast. The pollen diagram from Piantarella 1 (Fig. 8A) reveals low AP values since the beginning of the sequence (always <30%), therefore demonstrating the existence of open vegetation during the early Neolithic in southern Corsica. Thermo-Mediterranean scrublands (maquis in Fig. 8B) would have been dominant in the landscape but showed a decreasing trend due to the expansion of grassland, ruderals and Asteraceae, caused by human impacts (Fig. 8A and 8B). The record of Piantarella core 1 is notable for the early evidence of human impacts during the Early Neolithic in southern Corsica. A phase of more intense human impact is evident during ~7.3-7.2 cal kyr BP, with the

regression of maquis, the expansion of grassland, and occurrence of the pollen of Cerealia-type and the spores of coprophilous fungi (Fig. 8B). The presence of coprophilous fungi during the Early Neolithic ~~shows-suggest~~ that domesticated animals were introduced to the island at the same time as cereals, and therefore that the first Neolithic communities in Corsica practiced agriculture and animal husbandry. Fire could have been involved in maquis regression, as shown by the identification of *Erica* and *Arbutus* macroscopic charcoal at 7358 and 7273 cal yr BP, and at 368 cal yr BP, respectively (Fig.8B). This evidence of human impact is —consistent with the archaeological record of the area, with Early Neolithic sites discovered at Araguina Sennola (7786-7011 cal yr BP; Soula, 2012), Longone (7496-6894 cal yr BP; Lugliè, 2018), Abri du Goulet (EN without ¹⁴C dating). This finding is the earliest evidence of agriculture in Corsica and is consistent with traces of human presence in Sicily and Malta at ~7.5 cal kyr BP due to Neolithic expansion (Tinner et al., 2009; Djamali et al., 2013).

5.3.2. Middle-Late Neolithic (~6.8-5.0 cal kyr BP)

Due to marine incursion, the pollen record from Piantarella does not record the vegetation evolution during 7.2-6.6 cal kyr BP. The pollen diagram for Piantarella 3 (Fig. 8A) has low AP values from the beginning of the sequence (always <50%), and therefore the existence of an open vegetation during the Middle Neolithic (6615-6426 cal yr BP). Two pronounced phases of impact by Middle Neolithic communities are attested during 6615-6582 cal yr BP (decrease in forest and maquis, and increases in grassland, with peaks in Asteraceae and the occurrence of Cerealia-type) and during 6491-6426 cal yr BP (decrease in maquis, increased grassland, with a peak in Asteraceae and the occurrence of Cerealia-type and coprophilous fungi) (Fig. 8B). This

evidence of human impacts was likely associated with occupation in Araguina Sennola and Monte Leone (6897-6441 cal yr BP; Soula, 2012).

The Late Neolithic (5881-5293 cal yr BP) vegetation is characterised in Piantarella 3 by the decline of mesic vegetation, the increase in evergreen sclerophyllous forest and the expansion of shrubs (*Erica* and *Cistaceae*) (Fig. 8A). This vegetation succession could be the result of climate change, with progressively drier summers in the Mediterranean region during the transition to the Late Holocene. However, human impact may have also had a role in landscape changes during the Late Neolithic, due to the frequent presence of *Cerealia*-type, showing the impact of farming activity during the Late Neolithic (except during ~5.9-5.6 cal kyr BP, suggesting a probable lower population). Phases of higher human impact are defined by the occurrence of *Cerealia*-type pollen and coprophilous fungal spores, in some cases in the context of a decline of sclerophyllous forest (minor during ~5.6-5.5 cal kyr BP and more intense during 5400-5300 cal yr BP), and the expansion of maquis which colonized degraded sclerophyllous forest (during ~5.4-5.3 cal kyr BP) (Fig. 8B). The communities inhabiting Araguina Sennola (settled from the Early Neolithic to the Chalcolithic, 7786-3556 cal yr BP), would have been the responsible for these anthropogenic impacts.

In the north, the pollen diagram from Saint Florent (Fig. 6A) shows relatively high AP values (60-80%) from the Mid Holocene to modern times (~6.3-0.5 cal kyr BP). Although *Cerealia*-type pollen is absent during the Middle Neolithic at Saint Florent, possible evidence of human impact is documented at ~6.2 cal kyr BP, with the expansion of maquis associated with decreases in *Pinus*, and mesic and sclerophyllous trees (Fig. 6B). Stronger evidence of human impacts is documented during the Late Neolithic. *Cerealia*-type pollen is present at 5870-5817, 5439, 5224, and 5139-5078 cal yr BP, in some cases coinciding with the presence of the spores of coprophilous fungi

(at 5817 and 5180-5119 cal yr BP) (Fig. 6B). In addition, in some cases phases of greater human impact are defined by the occurrence of *Cerealia*-type pollen and the spores of coprophilous fungi, in the context of decline of forests (riparian during ~5.9-5.8 cal kyr BP and mesic and sclerophyllous forest during ~5.2-5.0 kyr BP) and the expansion of maquis (Fig. 6B). The evidence of human impact in Saint Florent is consistent with the archaeological record. The first evidence for Neolithic activity is during the early Neolithic (at the sites of Strette and Grotta Scritta), and this area experienced population growth during the Middle and Late Neolithic. The limited evidence for human impact during the Middle Neolithic may be because the sequence starts at ~6.3 cal kyr BP and part of the Middle Neolithic occupation predates this (Strette: 7027-6412 cal yr BP; Tèpa di Lupinu: 6672-6497 cal yr BP; Soula, 2012). The evidence of possible human impact at ~6200 cal yr BP may be related to Middle Neolithic occupation at Scaffa Piana (6254-5373 cal yr BP; Magdeleine and Ottaviani, 1983) and Monte Revincu (6309-5879 cal yr BP). Greater human impact during the Late Neolithic would be further related to occupation in Scaffa Piana, Monte Revincu, and Strette (the latter occupied until the Chalcolithic, ~3.8 cal kyr BP). Deforestation started in the final few centuries of the Late Neolithic and lasted until the Chalcolithic period (~4.0 cal kyr BP), demonstrating the impact of permanent settlement in the region, in which the communities inhabiting Strette would have played an important role.

6. Conclusions

Since the prehistoric period, both climatic and anthropic factors have combined to significantly modify the coastal landscape in several areas of the Mediterranean. In this study, we have reconstructed the complex interplay between these factors in the

1018 evolution of the coastal landscape of Corsica, a major Mediterranean island that is
1019 relatively little investigated. Our principal findings are as follows.

1020 At ~7.8 cal yr BP, the first farmers arrived in Corsica and found a suitable environment
1021 for developing a subsistence economy. This environment consisted mainly of freshwater
1022 pools close to the shoreline, which offered a favourable location for agriculture and
1023 therefore for the establishment of a permanent settlements.

1024 During the Early Neolithic, postglacial RSL rise caused major changes in local coastal
1025 environments This transgression had varying impacts on the different coastal sectors of
1026 Corsica. Salt intrusion in the freshwater bodies resulted in the formation of brackish
1027 environments in the southern coast, even though freshwater conditions persisted locally
1028 during the Middle and Late Neolithic. A similar process occurred in the northern coast
1029 during the Middle Neolithic (~6.3-5.7 cal kyr BP), indicating the resilience of riparian
1030 communities despite the general spread of brackish environments. At the transition from
1031 the mid to the late Holocene, increases in both salinity and aridity caused major
1032 landscape changes, including the significant expansion of saline marshlands (dominated
1033 mainly by *Chenopodiaceae*).

1034 Our results also provide new insights into the vegetation history of Corsica, especially
1035 regarding the role of *Erica* in the original Holocene landscape. Our data clearly indicate
1036 that an *Erica arborea* - *Quercus ilex* forest transition occurred before 6.3 cal kyr BP,
1037 due to Neolithic human impacts, as previously proposed by Reille (1992a). However,
1038 our records from southern Corsica suggest a different pattern of vegetation dynamics,
1039 characterized by the decline of *Erica* after 7.3 cal kyr BP, most likely related to *E.*
1040 *arborea* deforestation by Neolithic communities. At this time, the environment was
1041 more arid and dominated by open vegetation, with the minimal occurrence of *Quercus*
1042 *ilex-coccifera*.

Despite the fact that significant environmental changes would have been associated with changes in climate and RSL at the local scale (e.g. the expansion of marshland and increasing salinity after the 4.2 ka event), Holocene climatic oscillations did not have major regional effects on the vegetation of Corsica. On the contrary, human activities appear to have played an important role in landscape transformation since the early Neolithic. The earliest evidence of agriculture is documented in South Corsica at 7.4 cal kyr BP. Different phases of human impact during the entire Neolithic are indicated by the presence of Cerealia-type pollen and the spores of coprophilous fungi, by phases of forest regression, and by the expansion of grassland and/or shrubland. In North Corsica, the first evidence of Cerealia-type pollen is only documented since the Late Neolithic (5.8 cal kyr BP), and evidence of evergreen oak deforestation is recorded between 5.0 cal kyr BP to the end of the Chalcolithic period (~4.0 cal kyr BP). Nevertheless, major human impacts leading to open landscapes did not occur until historical times in northern and eastern Corsica, especially since the Middle Ages.

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Figure captions:

Figure 1. Location of the study area, the analysed cores, and archaeological sites cited in the text (left) and detailed LiDAR maps (right).

Figure 2. Age-depth models for the five studied cores, based on AMS radiocarbon dating. Age estimates for the entire profiles were obtained by fitting smoothing splines (Piantarella 1, 3 and Palo) or by linear interpolation (Piantarella 2 and Saint Florent) using Clam 2.2 (Blaauw, 2010).

Figure 3A. Sedimentological data for Palo (East Corsica). 3B. Core profile and sedimentological data for Piantarella (South Corsica). 3C. Core profile and sedimentological data for Saint Florent (North Corsica). Laser granulometry was only conducted on Piantarella core 3 for technical reasons (the technique can only be applied to sediments finer than 2 mm and most of the Piantarella 1 and 2 core material contained mixed sediments, composed of fine and very coarse material).

Figure 4. Ostracod content in the context of the sedimentary units of core P1 (Piantarella site) and related depositional environments. The vertical distribution of the most common taxa and ecological groups are reported as percentages. Faunal abundance values (no. of valves/g) and samples containing rare species (< 50 valves) are also shown. The ecological groups are defined following Mazzini et al. (2017) and references herein. Freshwater to low brackish species (*Ilyocypris* spp., *H. salina*); euryhaline species (*C. torosa*); brackish-marine species (*L. elliptica*, *L. stellifera*, *L. lagunae*, *C. fischeri*, *X. communis*, *X. decipiens*, *X. dispar*, *H. viridis*) and coastal-shallow marine (i.e. *Aurila* spp., *Loxoconca* gr. *exagona*, *L. rhomboidea*, *Palm. turbida*, *Pont. turbida*, *Semicytherura* spp.).

Figure 5. Ostracod content in the context of the sedimentary units of core SF (Saint Florent site) and related depositional environments. The vertical distribution of the most common taxa and ecological groups are reported as percentages. Faunal abundance values (no. valves/g) and samples containing rare species (< 50 valves) are also shown. The ecological groups are defined following Mazzini et al. (2017) and references herein. Freshwater to low brackish species (*Candona* species, *P. albicans*); euryhaline species (*C. torosa*); brackish-marine species (*L. elliptica*, *L. stellifera*, *L. lagunae*, *L. lacertosa*, *L. bacescoi*, *C. fischeri*, *X. communis*, *X. dispar*) and coastal-shallow marine (i.e. *Aurila* species, *Loxoconca* gr. *exagona*, *L. rhomboidea*, *Palm. turbida*, *Pont. turbida*, *Semicytherura* spp., *C. whitei*).

Figure 6A. Percentage pollen diagram from the Saint Florent core (North Corsica), showing selected pollen taxa and plotted as a function of age (cal yr BP). Colour silhouettes show $\times 2$ exaggeration of scale ($\times 5$ for rare taxa). Values <1% are represented by dots. 6B. Pollen and NPP synthesis diagram. Red shading indicates phases of human impact, dark blue increases in salinity, and sky-blue freshwater phases). Pollen categories (also valid for Figs. 7B, 8B and 10): mesic (deciduous *Quercus*, *Corylus*, *Fagus*, *Tilia*, *Carpinus*, *Acer*); riparian (*Alnus* cf. *glutinosa*, *Alnus* cf. *suaveolens*, *Ulmus*, *Fraxinus*, *Salix*, *Populus*); evergreen sclerophyllous (*Quercus ilex-coccifera*, *Quercus suber*-type, *Olea*, *Phillyrea*, cf. *Juniperus*); maquis (*Erica*, *Arbutus unedo*, *Pistacia*, Cistaceae, *Ephedra*, *Thymelaea*, *Asphodelus*); grassland taxa and ruderals (Poaceae, *Artemisia*, *Plantago*, *Plantago major-media*, *Rumex*, *Urtica*, Apiaceae, Brassicaceae), Asteraceae total (*A. liguliflorae*, *A. tubuliflorae*, *Aster*-type,

1524 *Cirsium*-type, *Centaurea*), Coprophilous fungi (*Sordaria*-type, *Cercophora*-type,
 1525 *Podospora*-type, *Sporormiella*, *Delitschia*), Carbonicolous-lignicolous fungi
 1526 (*Gelasinospora* HdV-2, *Neurospora*, *Coniochaeta* cf. *ligniaria*, *C. xilariispora* HdV-6,
 1527 *Kretzschmaria deusta*, types UAB-9, UAB-11, UAB-12 and UAB-38), aquatic and
 1528 hygrophilous taxa (Cyperaceae, *Typha*, *Typha-Sparganium*, *Myriophyllum*, *Nuphar*);
 1529 algae (*Spirogyra*, *Spirogyra* HdV-210, *Spirogyra reticulata*, *Zygnema*-t, *Pediastrum*,
 1530 *Mougeotia*, *Debarya*, *Closterium*), total *Isoetes* (*Isoetes*, *Isoetes boryana*), other
 1531 pteridophytes (monolete spores, *Polypodium*, *Pteridium*, *Osmunda*-type,
 1532 *Ophioglossum*-type and other trilete spores), salt-tolerant plants (Chenopodiaceae and
 1533 *Tamarix*).

1534 Figure 7A. Percentage pollen diagram from the Palo core (East Corsica) showing
 1535 selected pollen taxa and plotted as a function of age (cal yr BP). Colour silhouettes
 1536 show $\times 2$ exaggeration of scale ($\times 5$ for rare taxa). Values $< 1\%$ are represented by dots.
 1537 6B. Pollen and NPP synthesis diagram. Red shading indicates phases of human impact,
 1538 dark blue increases in salinity, and sky-blue freshwater phases).

1539 Figure 8A. Percentage pollen diagram from Piantarella cores 1, 2 and 3 (South Corsica)
 1540 showing selected pollen taxa and plotted as a function of age (cal yr BP). Colour
 1541 silhouettes show $\times 2$ exaggeration of scale ($\times 5$ for rare taxa). Values $< 1\%$ are
 1542 represented by dots. 6B. Pollen and NPP synthesis diagram. Red shading indicates
 1543 phases of human impact, dark blue increases in salinity, and sky-blue freshwater
 1544 phases).

1545 Figure 9. RSL reconstruction for northern (A) and southern (B) Corsica. Red boxes and
 1546 blue triangles are the RSL index points and marine limiting points, respectively. They
 1547 are derived from the cores obtained from Piantarella (PT) and Saint Florent (SF). Grey
 1548 boxes are the previously available RSL index points in Northern and Southern Corsica
 1549 (Vacchi et al., 2018). The dimensions of the boxes and lines are based on elevation and
 1550 age errors.

1551

 

PIANTARELLA 1

PIANTARELLA 2

PIANTARELLA 3

PALO

Site	Period	Date BP	Date cal BP	Date cal BC	Reference
North Corsica					
Strette	Early Cardial Neolithic	6480±480	<i>8343-6351</i>	<i>6393-4401</i>	Lugliè, 2018
	Early Cardial Neolithic	6420±300	<i>7926-6667</i>	<i>5976-4717</i>	Lugliè, 2018
	Middle Neolithic	5910±130	7027-6412	5077-4462	Soula, 2012
	Chalcolithic	<i>ca. 5000-3800</i>			Soula, 2012
GrottaScritta	Early Cardial Neolithic	<i>ca. 7800-7000</i>			Tozzi and Weiss, 2001
Tepa di Lupinu	Middle Neolithic	5795±35	6672-6497	4722-4547	Soula, 2012
ScaffaPiana	Middle Neolithic	5360±100	6313-5921	4363-3971	Soula, 2012
	Middle Neolithic	5330±100	6297-5916	4347-3966	Soula, 2012
	Middle Neolithic	5320±100	6295-5912	4345-3962	Soula, 2012
	Late Neolithic	4775±90	5662-5311	3712-3361	Soula, 2012
Monte Revincu	Middle Neolithic	5410±40	6297-6177	4347-4227	Soula, 2012
	Middle Neolithic	5405±70	6309-5997	4359-4047	Soula, 2012
	Middle Neolithic	5405±55	6300-6171	4350-4221	Soula, 2012
South Corsica					
AraguinaSennola	Early Cardial Neolithic	6650±140	7786-7276	5836-5326	Lugliè, 2018
	Early Cardial Neolithic	6430±140	7582-7011	5632-5061	Lugliè, 2018
	Chalcolithic	3980±120	4825-4148	2875-2198	Soula, 2012
	Chalcolithic	3550±120	4156-3556	2206-1606	Soula, 2012
Longone	Early Epicardial Neolithic	6325±140	7496-6894	5546-4944	Lugliè, 2018
Abri du Goulet	Early Cardial Neolithic	<i>ca. 7800-7000</i>			Lanfranchi, 1976
Monte Leone	Middle Neolithic	5855±95	6897-6441	4947-4491	Soula, 2012

Table 1. Radiocarbon dates for Neolithic and Chalcolithic archaeological sites surrounding Saint-Florent (North Corsica) and Piantarella (South Corsica) pollen records. Dates in italic correspond to C14 showing high standard deviation and, therefore, low reliability.

Core id	X (WGS 84)	Y (WGS 84)	Length (m)	Elevation (mmsl)	Vertical error (± in m)
Saint-Florent	9.3043598	42.6721834	7.35	0.47	0.031
Palo	9.4133546	41.9592999	3.15	0.42	0.028
Piantarella 1	9.2201637	41.3748017	6.30	0.36	0.038
Piantarella 2	9.2206919	41.3733222	3.15	0.33	0.034
Piantarella 3	9.2198324	41.3754055	4.20	0.19	0.039

Table 2. Coring data

Sample depth (cm)	Lab. Code	Material	Calibration curve	Radiocarbon date BP	Cal. year BP (2 σ range)	Cal. yr BP in diagram
Saint Florent						
088	Poz-105070	Plant remains	IntCal13.14C	105.21 $\pm$ 0.31 pMC		-50
190	Poz-91737	<i>Cerastoderma glaucum</i>	Marine13.14C	2015 $\pm$ 30	1678-1504	1548
232	Poz-105071	Bulk sediment	Marine13.14C	3715 $\pm$ 30	3693-3504	3600
247	Poz-100791	<i>Posidonia oceanica</i>	Marine13.14C	4160 $\pm$ 30*	4355-4121	4196
445	Poz-101158	<i>Cerithium vulgatum</i>	Marine13.14C	4800 $\pm$ 35	5238-4947	5027
523	Poz-86616	<i>Posidonia oceanica</i>	Marine13.14C	4900 $\pm$ 40	5307-5054	5186
732	Beta-450510	<i>Posidonia oceanica</i>	Marine13.14C	5920 $\pm$ 30	6398-6267	6312
Palo						
090	Poz-76246	Bulk sediment	IntCal13.14C	1925 $\pm$ 30	1943-1818	1815
100	Poz-76247	Bulk sediment	IntCal13.14C	1925 $\pm$ 30	1943-1818	1931
143	Poz-76248	Wood	IntCal13.14C	2445 $\pm$ 30	2700-2359	2474
155	Poz-76249	Wood	IntCal13.14C	2480 $\pm$ 35	2723-2381	2602
161	Poz-76250	Wood	IntCal13.14C	2460 $\pm$ 30	2706-2378	2662
169	Poz-76251	Bulk sediment	IntCal13.14C	2645 $\pm$ 30	2840-2738	2737
194	Poz-76252	Wood	IntCal13.14C	2780 $\pm$ 30	2951-2794	2897
Piantarella 1						
079	Poz-96451	<i>Posidonia oceanica</i>	Marine13.14C	1230 $\pm$ 40	850-663	1225
191	Beta-479673	<i>Posidonia oceanica</i>	Marine13.14C	4230 $\pm$ 30	4402-4190	3894
513	Beta-479674	<i>Posidonia oceanica</i>	Marine13.14C	6660 $\pm$ 30	7248-7074	7192
625	Poz-96321	<i>Cerithium vulgatum</i>	Marine13.14C	6930 $\pm$ 50	7509-7307	7435
Piantarella 2						
072	SacA-54013	<i>Posidonia oceanica</i>	Marine13.14C	740 $\pm$ 30	431-285	357
124	SacA-54014	<i>Cerithium vulgatum</i>	Marine13.14C	4490 $\pm$ 30	4779-4537	4655
179	Poz-101157	<i>Cerithium vulgatum</i>	Marine13.14C	4520 $\pm$ 40	4808-4562	4689
238	Poz-101152	<i>Cerastoderma glaucum</i>	Marine13.14C	4520 $\pm$ 35	4803-4570	4693
Piantarella 3						
266	Poz-101153	<i>Cerastoderma glaucum</i>	Marine13.14C	5195 $\pm$ 35	5594-5453	5515
290	Poz-101154	<i>Cerastoderma glaucum</i>	Marine13.14C	5550 $\pm$ 40	6002-5777	5806
360	Poz-101155	<i>Cerastoderma glaucum</i>	Marine13.14C	5950 $\pm$ 40	6426-6261	6442
388	Poz-	<i>Cerastoderma</i>	Marine13.14C	6260 $\pm$ 60	6838-6526	6673

	101156	<i>glaucum</i>				
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Table 3. C14 results for cores Saint-Florent, Palo, Piantarella 1, 2 and 3.

Sample depth (m)	Lab. Code	Material	Radiocarbon date BP	Age cal BP (2 σ range)	Cal. yr BP in diagram	IR	RSL (m)
Saint Florent (0.47 m msl)							
0.88	Poz-105070	Plant remains	105.21 $\pm$ 0.31 pMC		-50	na	na
1.90	Poz-91737	<i>C. glaucum</i>	2015 $\pm$ 30	1678-1504	1548	msl to -1 m	-1.05 $\pm$ 0.6
2.32	Poz-105071	Bulk	3715 $\pm$ 30	3693-3504	3600	msl to -1 m	-1.47 $\pm$ 0.6
2.47	Poz-100791	<i>P. oceanica</i>	4160 $\pm$ 30*	4355-4121	4196	msl to -1 m	-1.62 $\pm$ 0.6
4.45	Poz-101158	<i>C. vulgatum</i>	4800 $\pm$ 35	5238-4947	5027	Belowmsl	-4.1 $\pm$ 0.1
5.23	Poz-86616	<i>P. oceanica</i>	4900 $\pm$ 40	5307-5054	5186	Belowmsl	-4.88 $\pm$ 0.1
7.32	Beta-450510	<i>P. oceanica</i>	5920 $\pm$ 30	6398-6267	6312	Belowmsl	-6.97 $\pm$ 0.1
Palo (0.42 m msl)							
0.90	Poz-76246	Bulk	1925 $\pm$ 30	1943-1818	1815	na	na

1.00	Poz-76247	Bulk	1925±30	1943-1818	1931	na	na
1.43	Poz-76248	Wood	2445±30	2700-2359	2474	na	na
1.55	Poz-76249	Wood	2480±35	2723-2381	2602	na	na
1.61	Poz-76250	Wood	2460±30	2706-2378	2662	na	na
1.69	Poz-76251	Bulk	2645±30	2840-2738	2737	na	na
1.94	Poz-76252	Wood	2780±30	2951-2794	2897	na	na
Piantarella 1 (0.36 m msl)							
0.79	Poz-96451	<i>P. oceanica</i>	1230±40	850-663	1225	msl± 0.5 m	-0,55±0.6
1.91	Beta-479673	<i>P. oceanica</i>	4230±30	4402-4190	3894	Belowmsl	-1,67±0.1
5.13	Beta-479674	<i>P. oceanica</i>	6660±30	7248-7074	7192	Belowmsl	-4,89±0.1
6.25	Poz-96321	<i>C. vulgatum</i>	6930±50	7509-7307	7435	Belowmsl	-6,01±0.1
Piantarella 2 (0.33 m msl)							
0.72	SacA-54013	<i>P. oceanica</i>	740±30	431-285	357	msl± 0,5	-0,39±0.6
1.24	SacA-54014	<i>C. vulgatum</i>	4490±30	4779-4537	4655	msl to -1	-0,53±0.6
1.79	Poz-101157	<i>C. vulgatum</i>	4520±40	4808-4562	4689	Belowmsl	-1,58±0.1
2.38	Poz-101152	<i>C. glaucum</i>	4520±35	4803-4570	4693	Belowmsl	-2,17±0.1
Piantarella 3 (19 cm msl)							
2.66	Poz-101153	<i>C. glaucum</i>	5195±35	5594-5453	5515	msl to -1	-2,09±0.6
2.90	Poz-101154	<i>C. glaucum</i>	5550±40	6002-5777	5806	msl to -1	-2,33±0.6
3.60	Poz-101155	<i>C. glaucum</i>	5950±40	6426-6261	6442	msl to -1	-3,03±0.6
3.88	Poz-101156	<i>C. glaucum</i>	6260±60	6838-6526	6673	msl to -1	-3,31±0.6

Table 4.

Depth (m)	Age cal BP	<i>Corylus</i>	<i>Erica</i> sp.	<i>E. scoparia</i> (seed)	<i>Arbutus</i>
Saint Florent					
1.45	843	X			
2.20	3013		X		
2.40	3918				X
2.80	4335		X		
2.90	4377		X		
3.90	4797		X		
4.90	5119		X		
Piantarella 1					
5.45	7273		X		
5.85	7358		X		
5.90	7368				X
6.05	7397		X		
Piantarella 2					
0.69	340		X		
1.30	4659		X		
Piantarella 3					
2.50	5293		X	X	
2.54	5350		X		
2.56	5379		X		

Table 5. Botanical macrofossils results.

Conflict of Interest Statement

The authors declare that there is no conflict of interest