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## Natural and anthropogenic dynamics of the coastal environment in northwestern Corsica (Western Mediterranean) over the past six millennia

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- 25 Abstract
- 26

27 The present paper provides new insights into the climatic and anthropic factors that influenced a 28 6000-year coastal evolution in northwestern Corsica, the third largest island of the western 29 Mediterranean. Pollen, microcharcoal, sedimentary and geochemical analyses were carried out 30 on a core drilled in the Crovani coastal wetland to reconstruct the regional drivers of landscape 31 change. We show that anthropogenic and climate-induced fires favoured the development of 32 Mediterranean maquis, dominated by Erica and Quercus ilex, from ca. 6000 to 3350 cal. BP. A 33 change in arboreal vegetation triggered a short but intense sediment input in the Crovani pond 34 between ca. 3350 and 3200 cal. BP. This is consistent with a coeval process of runoff recorded in 35 several coastal sites of western Corsica and related to an arid climate change occurred in many 36 sites of the western Mediterranean around 3200 years ago. We provide evidence of agriculture 37 during the Late Neolithic from ca. 3900 BC, which is much earlier than any archaeological 38 evidence previously available in this area of Corsica, followed by a progressive decline of arable 39 farming practices. Human impact has been responsible for a degradation of the maquis only from 40 approximately 3000 cal. BP, and it intensified in Roman times, when the area experienced the first phase of galena exploitation from the Argentella mines. Over the last 500 years, the present 41 42 work evidences a major development of Castanea related to cultivation during the Genoese 43 administration of Corsica. Our findings suggest that solar activity and the North Atlantic 44 Oscillation had an influence on centennial-scale forest cover variations during the last 6000 years.

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Keywords: Corsica, pollen, palaeoenvironments, isotope geochemistry, geoarchaeology, western
 Mediterranean, Holocene

48 49

#### 1. Introduction

50 The island of Corsica hosts the largest number of coastal wetlands among the Mediterranean islands 51 (Ghilardi, 2020 and 2021). Most of them formed after the Mid-Holocene sea-level stabilization that 52 occurred in the Mediterranean Basin between 7000 and 6000 cal. BP (Vacchi et al., 2016, 2018). 53 Amongst the ~200 coastal wetlands of the island, brackish lagoons and coastal ponds are the most 54 common geomorphological features (Ghilardi, 2020).

The remarkable potential of pollen analysis to trace the main changes in the costal landscape of the island was first highlighted by the excellent palynological work of Maurice Reille (Reille, 1984, 1991,1992a). However, these pollen data were not provided with a robust chronology and did not include the analysis of Non-Pollen Palynomorphs (NPPs) and other palaeonvironmental proxies from the same core. In the last few years, several Corsican wetlands situated at a short distance of the sea were the subject
 of multiproxy geoarchaeological research on the environmental impact of human activities, especially

62 in Prehistoric and Protohistoric times (Early Neolithic to Final Bronze Age, ca. 7500 BP to 2800 BP)

63 (Currás et al., 2017; Ghilardi et al., 2017a; Revelles et al., 2019; Vella et al., 2019; Figure 1). The

study of different palaeoecological proxies, such as ostracods, molluscs, and pollen, combined with the chronostratigraphy of sediments, has shown the interest of reconstructing both the paleogeography and the history of the vegetation of coastal Corsica starting from the ancient Neolithic (Cardial culture, starting from 7500  $\pm$  200 cal. BP; D'Anna et al., 2001; Lugliè, 2018).

- The information of palaeoenvironmental records from Corsica is paramount for detailed reconstructions of both land-use patterns and centennial-scale climate changes in the Mediterranean Basin. Indeed, the island was a crossroad for many European and North African populations in the conquest of the Mediterranean and occupies a strategic geographical location, potentially sensitive to both North Atlantic climate patterns and north African atmospheric drivers (Sabatier et al., 2020).
- The aim of this paper is to outline the landscape evolution in northwestern coastal Corsica over the last six millennia, taking advantage of the recent progress in palaeoenvironmental reconstructions (Henry ed., 2020), chronological models (Reimer at al., 2020), and new insights into the centennialscale patterns of atmospheric circulation during the Middle and Late Holocene (Franke et al., 2017; Di Rita et al., 2018a; Sabatier et al., 2020).

78 Our new palynological and stratigraphical data are addressed to contribute to prominent unsolved 79 questions about times and drivers of vegetational change in Corsica, with a special focus on the 80 replacement of *Erica* shrublands with *Quercus ilex* woody formations during the Middle Holocene. 81 A second key topic is the origin and development of land use practices in northwestern Corsica. In 82 Neolithic times, there is sparse archaeological evidence for cereal cultivation and pastoral activities 83 along the coasts of Corsica. Cereal cultivation was revealed by pollen analyses only in the eastern 84 plain of Corsica and in the Saint Florent and Bonifacio-Piantarella areas (Currás et al., 2017; Revelles 85 et al., 2019), while the osteological identification of mammals buried in sheltered caves from southern 86 and northern Corsica provided evidence about the development of stockbreeding (Vigne, 1984, 1987). 87 A third unsolved question is related to the controversial role of climate changes in modifying the 88 vegetational landscape of Corsica. While at millennial time scale the influence of climate changes on 89 the vegetation and fires of the island has been clearly recognized (Reille 1992a; Leys et al., 2013; 90 Revelles et al., 2019; Lestienne et al., 2020a, b), the role of rapid climate changes (RCC) has been 91 seldom evoked in the regional palaeobotanical narrative. The apparent lack of vegetation responses 92 to centennial climate changes was attributed to either the overshadowing effect produced by local 93 resilient shrublands (Revelles et al., 2019) or the geographical position of Corsica, located in a 94 possible climate-unsensitive transitional area between the central and western Mediterranean (Di Rita

and Magri, 2019), two regions where RCC often produced contrasting moisture changes (Di Rita et
al., 2018a).

97 New detailed palaeoenvironmental data from Corsica are thus needed to disentangle these questions,
98 which are relevant for a better understanding of the natural and anthropogenic landscape changes in
99 the Mediterranean during the Holocene.

100

#### 101 **2. Study area**

#### 102 2.1. Present day landscape and vegetation

The Crovani pond is located in NW Corsica, in the westernmost part of a ~1 km<sup>2</sup> coastal plain (Fig. 104 1A). The plain collects the waters from two catchment basins with intermittent flow: the Argentella-105 Cardiccia streams (catchment basin ~6 km<sup>2</sup>), incising metamorphic rocks (shales and micaschists) 106 and syenogranite, and the Marconcellu-Fiuminale streams (total catchment area: ca. 23 km<sup>2</sup>), draining 107 granodiorites, syenogranite, and Pliocene to Pleistocene screes in the lowermost river course (Fig. 108 1B).

109 Corsica has a typical Mediterranean climate highly influenced by its relief topography. The mean 110 annual temperature on the whole Island ranges between 14.5°C and 16.5°C and the mean annual 111 precipitation is 890 mm per year. On the coastal area, mean annual temperature is higher (17°C) and 112 freezing temperatures during the year are very seldom reported (Vella et al., 2019).

113 The Crovani wetland covers an area of  $\sim 0.3 \text{ km}^2$  behind a thick coastal barrier  $\leq 5.30 \text{ m}$  above the 114 mean sea level (amsl), made up of large well-rounded pebbles and cobbles (Fig. 2). The pond, which 115 is at 0.75 m amsl in the winter, is seasonal dry in the summer and has no direct link to the sea.

116 The surrounding wetland is a protected area, being included in the ZNIEFF (Zone naturelle d'intérêt

117 *écologique, faunistique et floristique*) n. 940004139 '*Etang et zones humide de Crovani*' with the aim

118 of preserving the following angiosperm species: *Euphorbia peplis* L., *Polygonum scoparium* Req. ex

119 Loisel., Ranunculus ophioglossifolius Vill., Staphisagria picta (Willd.) Jabbour, Tamarix africana

120 Poir., and Vitex agnus-castus L. The pond is surrounded by a belt of T. africana and is characterized

121 by a wet meadow covered by palustrine species dominated by *Bolboschoenus maritimus* (L.) Palla,

122 Juncus acutus L. and Juncus maritimus Lam. The coastal bar is occupied by a population of Pistacia

123 *lentiscus* L. and, on the top of the beach, by one of the most important Corsican populations of *Vitex* 

124 agnus-castus (https://inpn.mnhn.fr/zone/znieff/940004139). In spring, the very rare S. picta grows

among the pebbles (Jeanmonod and Schlüssel, 2006). The woody vegetation of the site consists of a

126 degraded maquis with Erica arborea L., Arbutus unedo L., Pistacia lentiscus L., Phillvrea

127 *angustifolia* L. and sparse *Quercus ilex* L. (Reille, 1992a).

128

#### 129 2.2. Local archaeology and history of the human occupation

The first evidence of human settlement in Corsica dates back to the Mesolithic (Lugliè, 2018). Abundant archaeological material allows to reconstruct the Neolithic settling history of the island (Lugliè, 2018; Revelles et al., 2019). In northern Corsica a rich archaeological background is found in a Mesolithic to Early Neolithic occupation in the Nebbiu area, at the Saint-Florent/Patrimonio sites (Revelles et al., 2019). In the Balagne area, an important human occupation in a coastal context is attested by the Early Neolithic site (Cardial culture) of La Petra, situated on a peninsula north of the modern town of L'Île Rousse (Weiss, 2010). In the Luzzipeu sector, situated in the southern part of the Balagne micro region, where the Crovani

In the Luzzipeu sector, situated in the southern part of the Balagne micro region, where the Crovani 138 pond is located (Fig. 1A), despite the paucity of recognized prehistoric settlements and uncovered 139 archaeological material, there is evidence of occupation during the Final Neolithic (starting from ca. 140 2800 cal. BC) at Teghja di Linu (Fig. 1A). The last site consists in a small village composed of huts, 141 located at an elevation of ~40 m amsl at ~1.5 km distance from the Crovani pond, where lithics were 142 discovered together with a menhir statue (Sicurani, 2008; Sicurani and Martinet, 2019; Ghilardi, 143 2020). Possible evidence of occupation during Late Neolithic times is also possible, but the lithics 144 uncovered are still under investigation (Sicurani and Martinet, 2019). Due to the presence of acidic 145 soils, derived from the erosion of the granitic bedrock, preservation of biological remains and archaeological material in this stratigraphical context is difficult, so that there is no organic material 146 147 left in the archaeological layers that may help to evaluate the type of activities developed at the Teghja 148 di Linu site. Excavations conducted over the last two decades have revealed the existence of a habitat 149 composed of several circular large structures, delimited by tremendous rounded granitic boulders.

150 Protohistoric settlements are hardly documented in the Luzzipeu lowlands. Bronze Age sites are situated more inland, generally on top of hills (Peche-Quilichini, 2011). Iron Age and Roman times 151 152 are poorly documented, but archaeological surveys have revealed the presence of *tegulae* within the mining complex of the Argentella, in use in the 19<sup>th</sup> to 20<sup>th</sup> century CE, indicating a first phase of 153 galena exploitation (Leleu, 2021). This sparse human occupation from Bronze Age to Roman times 154 155 radically contrasts with the Medieval archaeological remains attested at San Larenzu and San Quilicu (Fig. 1A). Both are Romanic churches dated from the 11<sup>th</sup> Century CE and nowadays almost 156 disappeared due to their gradual destruction. From the Genovese administration to the French 157 158 administration, the region was attractive for the exploitation of natural resources, especially galena minerals. Evidence for mining from the 16<sup>th</sup> to the early 20<sup>th</sup> centuries has been recorded (Leleu, 159 160 2021) but its impact in terms of landscape changes has never been investigated.

#### 162 **3. Materials and Methods**

163

164 In this paragraph we present a synthetic version of materials analysed and techniques we used. For a 165 more exhaustive explanation of the methodology applied in this research we refer to information

- 166 reported in the Supplementary data.
- The analyses presented in this study were carried out on a 6.25 m long sediment sequence, which was
  collected with a 50-mm vibracore (COBRA TT equipment Atlas Copco) in the central part of the
  Crovani pond in August 2018 (Fig. 2).
- The chronostratigraphy of the core was established using a series of 14 AMS radiocarbon determinations made in the Poznan and Gliwice (Poland) Radiocarbon Dating Laboratories. The Bayesian age-depth model (Fig. 3) was constructed using the software Bacon version 2.5.5 (Blaauw and Christen, 2011) with dates calibrated using the IntCal20 curve (Reimer et al., 2020).
- Loss-on-ignition (LOI) measurements were performed on sediment samples of approximately 1 g
  taken at 10 cm intervals throughout the sequence, following the standard procedures published in
  Dean (1974) and Bengtsson and Enell (1986). (Fig. 4).
- Samples used for LOI measurements were also analysed for granulometry. The grain-size distribution
  of the fine fraction (<2 mm) was measured by laser diffraction granulometry at CEREGE.</li>
- A *C/N* analysis was carried out on 28 samples from the core, selected according to their organic matter content: a minimum of 5% by weight of organic matter was required to continue. The method by Stax and Stein (1993) was used as a basis for the preparation of the samples. Results were obtained using an elementary analyser (Vario Microcube, Elementar) coupled to a mass spectrometer (Isoprime
- 183 1000) (Fig. 4).
- 184 The bulk mineralogy was measured on 28 samples in the upper 261 cm of the core. Most of the 185 samples were retrieved from clayey sediments between 116 and 261 cm (n=20), with a sampling resolution of 4 cm. In addition, 8 samples were retrieved between 11 and 106 cm. About 1 gram of 186 187 dried bulk sediment sample was hand ground for mineralogical analyses. X ray diffraction (XRD) 188 patterns of non-oriented powders (Moore and Reynolds 1997) were acquired between 2 and 30° 20 angle by using a Bruker D8-Advance Eco 1 Kw diffractometer equipped with a ceramic copper (Ka 189 190 radiance with  $\lambda = 1.5418$  Å). The XRD data measured under a current intensity of 25 mA and a 191 voltage of 40 KV were recorded with a Lynxeye Xe energy dispersive detector in the laboratory 192 AGEs at the University of Liège. The minerals were identified by their peak positions and their 193 abundance was calculated from the intensity on selected diffraction peaks (Cook et al. 1975).
- 194 The bulk samples for Pb isotopes analyses were digested using a tri-acid attack of HF/HNO<sub>3</sub>/HCl in
- a laminar flow hood. The Pb purification was made according to the procedures published in Weis et

- al. (2006). The Pb isotopes were measured by static multicollection in dry mode on a Nu Plasma I MC-ICP-MS instrument at the University of Brussels. The values were normalized using the recommended NBS981 values ( $^{208}$ Pb/ $^{204}$ Pb 36.7219 ± 61,  $^{207}$ Pb/ $^{204}$ Pb 15.4963 ±17,  $^{206}$ Pb/ $^{204}$ Pb 16.9405 ± 24) from Galer and Abouchami (1998). The Pb isotopes ratios were measured on 24 clayey samples retrieved in unit VI and VIII with a ~5 cm sampling resolution between 11 and 260 cm (Table
- 201 **S**1).
- In addition, some Pb-bearing minerals were collected in different Corsican ores or mineralised veins
  on the Paleozoic granites from west Corsica (Fig. 5). We have sampled the main Pb mineral galena
  (PbS) and also some Pb-bearing minerals like arsenopyrite (FeAsS). Galena was sampled in the mine
  of Argentella, 2.5 km from the Crovani pond but also in the mine of Lozari (along the northwestern
  coast, east of Ile Rousse) and in a mineralized vein in Prunelli (south of Porto see locations in Fig.
  In addition, an arsenopyrite mineral sample was collected in the Finosa Pb-Zn-Ag ore close to
- 208 Ghisoni (Fig. 1).

209 Pollen analysis was carried out on 62 samples. Pollen extraction followed the standard procedures

summarized by Magri and Di Rita (2015). Pollen grains and NPPs were identified by light microscope

- at 400 and 640 magnifications, with the help of both pollen morphology atlases (e.g., Reille, 1992b;
- Beug, 2004) and NPPs reference articles (e.g., Van Geel, 2001; Cugny et al., 2010; Gelorini et al.,
- 213 **2011**).
- Microcharcoal analysis was carried out to reconstruct fire history, following the procedures described by Clark (1982). A series of 150 microscope fields were checked for each sample. Microcharcoals smaller than 5 µm were excluded from the sum. The computer program Psimpoll 4.27 (Bennett, 2009) was used to plot the percentage and concentration diagrams, as well as to subdivide the pollen record into 8 local assemblage zones, numbered from the base upwards and prefixed by the site abbreviation CRO, by means of the CONISS method (Grimm, 1987).
- A REDFIT spectral analysis (Schulz and Mudelsee, 2002) using the PAST 3.2 software (Hammer et al., 2001) was applied to the unevenly spaced time series represented by the total Arboreal Pollen (AP) percentages to detect the possible occurrence of a fundamental tempo in the forest cover changes.
- 224

#### 225 **4. Results**

226 *4.1.Chronostratigraphy* 

Based on the laser grain size determination and on the organic matter/carbonate contents, eight
stratigraphic units were defined from the bottom to the top (Fig. 4).

Unit I is found between 6.25 and 5.95 m depth. It consists of a mixture of well-rounded pebbles cemented within a sandy matrix and grey clays containing from 2 to 5% of organic matter. Due to the paucity of organic material, radiocarbon dating of this sedimentary unit was impossible.

Unit II is found between 5.95 and 5.45 m depth. It comprises medium to coarse grey sands with local

intercalations of angular gravels (centimetric in size). Organic matter and carbonate content are very

low (1-2%), hindering any radiocarbon dating of Unit II. No biomarkers were identified.

233

235 Unit III is encountered between 5.45 and 3.73 m depth (~6300-5170 cal. BP; ~4350-3220 BC). It

consists of homogeneous grey clays. The organic matter content ranges between 10 and 15% whilecarbonate content shows values comprised between 6 and 9%.

238 Unit IV occurs from 3.73 to 2.95 m depth (5170-4760 cal. BP; 3220-2810 BC). It shows features

similar to Unit II. It consists of coarse sands with intercalated layers of gravels with sharp edges,

240 witnessing variations in the energy of deposition, in particular at the point of changeover with Unit

- 241 III. In the lowermost part of Unit IV, a layer of 15 cm consists of angular gravels without sedimentary
- 242 matrix. Organic matter and carbonate contents (both < 2%) are low, like Unit II. Radiocarbon dating

243 of this lowermost portion is consistent with a time interval encompassing the Late to Final Neolithic.

Unit V, between 2.95 and 2.72 m depth (4760-4630 cal. BP; 2810-2680 BC), consists of organic
coarse sandy clays. Organic matter content increases upwards (1-7%). The carbonates content is
lower than 2%.

Unit VI is found from 2.72 and 1.42 m depth (4630-3320 cal. BP; 2680-1370 BC) and exhibits sedimentological parameters similar to Unit V. It consists of organic clays with 10-20% of organic matter and  $\leq 8\%$  of carbonate. The XRD mineralogy (Fig. S1) reveals the dominance of detrital minerals (~50% of quartz, K-feldspars and plagioclase with traces of amphibole and chlorite). They are associated to clayey minerals (~30% of total undifferentiated clays), aragonite (3 to 8%) from biogenic fragments and evaporites (8% < halite < 12% - Fig. 4). Radiocarbon dating of the unit is consistent with a time interval ranging from Final Neolithic to Middle Bronze Age.

Unit VII is encountered from 1.42 to 1.32 m deep (3320-3190 BP; 1370-1240 BC). It consists in a thin layer (10 cm) of homogeneous yellow fine sands showing a modal index of 90  $\mu$ m with a mean grain size of 20  $\mu$ m (fine silts). The granulometric analyses exhibit a multimodal distribution of the particles. Positive excursion in detrital minerals (cumulated abundance over 70 %). is observed for Unit VII and corresponds to a significant increase in quartz (28%) and plagioclase (25 %) and a relative drop in total clays minerals (13%) (Fig. S1).

Sedimentary Unit VIII is identified in the uppermost 1.32 m depth (3190-0 cal. BP; 1240 BC-1950
AD). Homogeneous grey clays record numerous traces of oxidation corresponding to rootlets. The
organic matter content is homogeneous (6 to 8%), while carbonate content is low (2-3%). The XRD

263 mineral association remains similar to unit VI, except the abundance of evaporites. A drop of halite 264 below 4% occurs between 166 and 150 cm, i.e. in the upper part of unit VII but close to the transition 265 with unit VI (Fig. 4). This sedimentary unit shows conditions similar to present day marshy 266 environments. The rate of sediment accumulation for Unit VIII is very low, with values of ~4.3 mm 267 per century.

268 269

#### 270 *4.2.C/N results*

The uppermost 2 m sediment, spanning the last four millennia, were investigated for C/N ratio (Fig. 4). The averaged C/N ratio is high (> 10) and exceeds a value of 16 above 1.16 m suggesting a mainly terrestrial origin of the organic matter. The values range between 11 to 14 from 1.16 to 2 m, indicating a mixture of organic matter from vascular plants and algae. The highest value (~30) measured at 1.36 m indicates an episode of high input of sediments of continental origin, with a mix of vascular plants and cellulosic plants, dated ca. 1430 to 1260 BC.

277

#### 278 *4.3. Lead isotopes analyses*

The three Pb isotopic ratios evolve in parallel in the 260-upper cm, from Final Neolithic to present (Fig. S2). The  ${}^{208}$ Pb/ ${}^{204}$ Pb ranges between 38.60 and 39.01 (average 38.9353 ±0.0019), the  ${}^{207}$ Pb/ ${}^{204}$ Pb between 15.65 and 15.68 (average 15.6703 ±0.0007), and the  ${}^{206}$ Pb/ ${}^{204}$ Pb between 18.61 and 19.11 (average 19.02 ±0.0008) (Table S1). Even if some scattering of the data is observed for the studied pre-Roman period (i.e., 260-93 cm), the isotopic Pb ratios depict a marked decreasing trend upwards. This major change starts at 73 cm (Fig. S2) during the Roman period and continues over the modern period. The lowest isotopic ratios are measured in the shallowest samples at 11 and 17 cm.

286

#### 287 *4.4.Pollen analysis and statistical analysis on pollen time series*

The results of pollen analysis are presented as: 1) a detailed percentage diagram, including most of the pollen taxa and a summary Arboreal Pollen (AP)/Non Arboreal Pollen (NAP) percentage diagram, plotted against age (Fig. 6); 2) a percentage diagram displaying the main NPPs (Fig. 7); 3) a synthetic diagram including cumulative pollen percentages of ecological groups (conifers, riparian trees, deciduous trees, evergreen trees and shrubs, OJCV (*Olea+Juglans+Castanea+Vitis*), anthropogenic herbs, other herbs, coprophilous fungi, and saproxylic and phytopathogenic fungi), AP percentage, the concentrations of AP and NAP, microcharcoals, and some climate proxies (Fig. 8).

295 The pollen preservation was good with percentages of undeterminable grains seldom exceeding 4%.

An average of 310 pollen grains of terrestrial taxa per sample were counted. The biodiversity was represented by 92 different pollen taxa (terrestrial + aquatic plants) summed to 45 types of ferns, algae, fungi, and other NPPs. The palynological richness, estimated by rarefaction analysis (Birks and Line, 1992), is always over 15 terrestrial pollen types per sample. Total pollen concentrations vary from 7000 to 321,000 terrestrial pollen grains/g sediment. The features of the local pollen assemblage zones are summarized in the Supplementary Materials.

A REDFIT analysis was applied to the unevenly sampled time series represented by the total AP percentages, which show a clear fluctuating trend consistent with changes in forest cover rather than random fluctuations due to pollen representation and preservation (Fig. 9).

The results of the REDFIT exhibit a peak in power spectrum exceeding 95% of the false-alarm levels of both  $\chi^2$  and Monte Carlo tests, corresponding to a statistically significant periodicity of ca. 228 years (time=1/frequency), and less significant frequencies centred at 996 and 430 years, which however exceed 90% of the false-alarm levels of both  $\chi^2$  and Monte Carlo tests (Fig. 9).

#### 309

311

#### 310 **5. Discussion**

#### 312 *5.1. Evolution of the vegetational landscape*

313 During the Middle and Late Holocene, from ca. 6100 to 1000 cal. BP (4150 BC-950 AD), the Crovani 314 pond was surrounded by a dense Erica-dominated tall maquis, accompanied by several evergreen 315 elements, such as Q. ilex, Phillyrea, Pistacia, and Olea (Figs 6, 8, and 10). This observation is 316 consistent with other palynological studies from southern Corsica (Reille, 1975, 1984; Revelles et al., 317 2019, Vella et al., 2019) and on the Cavallo island, situated in the strait of Bonifacio (Poher et al., 318 2017). An almost continuous record of Arbutus indicates that strawberry trees was a common 319 presence in the *Erica arborea* formations, as its pollen tetrads are poorly dispersed. The most 320 degraded sectors of this maquis vegetation were probably occupied by law shrublands of Cistus, 321 which played a prominent role in the dune and sandy soil vegetation together with Olea, Pistacia and 322 other thermophilous shrubs, as also reported from other coastal sites of western Corsica (Reille, 1992a). 323

The pollen record from Crovani provides new data to investigate the complex interplay between *Erica*-dominated and *Q. ilex*-dominated vegetation and their turnover in Corsica. According to Reille (1992a), *Erica* woodlands, representing the climax vegetation in lowland areas of western Corsica, underwent a major degradation process since the neolithization of the island, as a result of increasing human impact. It was largely replaced by *Quercus ilex* during the Mid- to Late Holocene (Reille, 1992a, Carcaillet et al., 1997). Recent palynological studies (Revelles et al., 2019) confirmed the anthropic causation of this vegetation turnover and suggested that it started with the development of 331 agropastoral practices during the Early Neolithic, hence significantly earlier than the period 332 previously identified by Reille (1992a). Similar vegetation dynamics were reported also in Sardinia, 333 where a clear development of *Quercus ilex*, leading to a partial or complete replacement of the late successional *Erica* shrublands, is recorded since the 6<sup>th</sup> millennium BP (Di Rita and Melis, 2013; 334 335 Beffa et al., 2016; Melis et al., 2017, 2018; Pedrotta et al., 2021). In contrast, the pollen record from 336 Crovani (Fig. 6) indicates that the frequencies of Erica were continuously high until ~2900 BP and 337 were not replaced by Q. ilex. Our pollen record even shows two temporary major increases in Erica 338 at the expense of holm oaks in the time-intervals 4700-4300 and 3350-2900 cal. BP. High frequencies 339 and concentrations of *Erica* and *Q. ilex* concur in depicting a *maquis* characterized by high biomass 340 and decomposed organic matter, as suggested by generally high values in the loss of ignition and a 341 significant presence of saproxylic and phytopathogenic fungi, such as Kretzschmaria deusta, 342 Asterosporium and Xylariaceae (Fig. 7)..

343 In Sardinia, Beffa et al. (2016) hypothesise that a protracted dominance of Erica and the absence of 344 evergreen oak forests in the first part of the Middle Holocene (until ca. 5300 cal. BP) were related to 345 warmer/drier summers and cooler/moister winters than today. They suggest that also in Corsica such 346 a climate regime, characterized by frequent and prolonged droughts during the spring and summer, 347 may have led to frequent seasonal wildfires advantaging communities dominated by Erica scoparia 348 and Erica arborea, which are two fire-adapted species able to quickly resprout and generate new 349 aboveground biomass after frequent and intense fires. In contrast, *Quercus ilex* is considered to have 350 been severely affected by natural and anthropogenic fires and favoured by a climate change leading 351 to increased summer rainfall and decreased fire occurred at the end of the Middle Holocene 352 (Colombaroli et al., 2009; Beffa et al., 2016; Pedrotta et al., 2021).

353 In contrast to this view, at Crovani, high concentrations of microcharcoal, reflecting fires, are 354 recorded in correspondence of high values of both *Erica* and *Q. ilex*. Contemporary high values of *Q*. 355 ilex and microcharcoal support the interpretation of Reille (1992a) and Carcaillet et al. (1997), which 356 suggest that the development of holm oak in Corsica was triggered by anthropogenic fires. At 357 Crovani, a substantial portion of the Mid-Holocene fires may be related to human activity, which is 358 witnessed by a significant presence of anthropogenic indicators (Figs 6-8). High frequencies of 359 microcharcoal in zones CRO-1 and CRO-2 are consistent with the coeval high incidence of fires 360 recorded in the region (Leys et al., 2014; Lestienne et al., 2020a, b), most of which are attributed to 361 human activity. According to Lestienne et al. (2020b), since 5000 cal. BP humans have taken control 362 of the fire regime through agro-pastoralism, favouring large and/or frequent fire events. For the same 363 reason, the marked decrease in microcharcoal recorded at Crovani during the Late Holocene after

- ~3350 cal. BP, which matches a decrease in anthropogenic pollen indicators, may reflect decreased
  human activity, at a time of an unsuitable climate for fires.
- Starting from ~2900 cal. BP, there was a general decline in *Erica*, opposed to an increase in holm oaks, which led to a turnover of the two woody taxa between 2300 and 1900 cal. BP. In this timeinterval, an increase in oaks may have been influenced by the forestry practices of Roman times. All
- the same, in the last ~2500 years, a clear development of cork oak in Corsica (Reille, 1984, 1992a),
- 370 Sardinia (Di Rita and Melis, 2013), and the western Iberian Peninsula (Carrión et al., 2000) may be
- 371 related to silvicultural practices.
- Between 1900 and 1000 cal. BP (pollen zone CRO-6), a new moderate increase in *Erica* at the expense of *Q. ilex* suggests a new expansion of the native *Erica*-dominated shrublands.
- Between 1000 and 500 cal. BP (pollen zone CRO-7), a major degradation of the forest cover is
- 376 shrubland. After ~ 500 BP, *Erica* and *Q. ilex* recovered, as recorded also in other sites of Corsica (e.g.

recorded, with a massive decline of the tall *maquis* that was replaced by *Cistus*-dominated low

377 Vella et al., 2019).

- 378 Modest oscillations of deciduous trees throughout the record (Fig. 6 and 8) suggest that they were 379 scarcely involved in the environmental processes influencing the evergreen vegetation, probably 380 because they were located at higher elevations in the island. Frequent finds of mesophilous trees such 381 as Fagus and Betula, which require temperate and humid conditions, confirm that part of the pollen 382 rain originated from the montane vegetation belt. The fingerprint of deciduous trees in the pollen 383 record of Crovani, as in other coastal pollen records of Corsica (Reille, 1992a; Currás et al., 2017; 384 Revelles et al., 2019), is clearly due the steep topography of the island, which determined a relatively 385 low distance of montane and sub-montane vegetation belts from the coast. However, it cannot be 386 excluded that sparse stands of mixed oak communities could also be preserved in humid areas at low 387 elevations, especially inside floodplain and riparian woodlands, dominated by Alnus, accompanied 388 by Salix, Tamarix, and possible wild Vitis, which are still documented in the area (Reille, 1992a).
- Conifers are mostly represented by *Pinus*, substantially reflecting the persistence of *Pinus nigra*subsp. *laricio* at montane and sub-montane elevations since the late glacial period (Leys et al. 2014).
  The occurrence of *Pinus pinaster* since the Bronze Age is probably related to human activity (Reille,
- 392 1992a). In addition to pine, conifers include taxa distributed in both lowland/coastal areas, such as
- *Juniperus*, and in montane sectors, such as *Abies* and *Taxus* (Fig. 7). Rare occurrences of *Picea*,
   whose current natural range does not include Corsica, are of distant origin.
- 395
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- 397

#### 398 5.2. Environmental responses to hydrological and morphosedimentary processes

- 399 The local aquatic environment outlined by the pollen record ranged from brackish (6100-3400 cal. 400 BP) to freshwater conditions (~3400 cal. BP-present day) (Fig. 10). This range is documented by the 401 presence of freshwater taxa, such as Spirogyra, Zygnema and Myriophyllum, salt-tolerant species, 402 such as Ruppia maritima, and marine organisms, represented by foraminiferal linings, pointing to 403 inputs of salt-water into the pond (Bellotti et al., 2016). This was likely related to the morphological 404 response of the pond to the Mediterranean sea-level rise whose average rates decreased from ~2 mm a<sup>-1</sup> at ~6100 BP to less than ~0.5 mm <sup>a-1</sup> in the last 3500 years (Vacchi et al., 2021). These major 405 changes in the rising rates probably have an influence on the connection of the pond with the open 406 407 sea as already observed in lagoonal setting both in Corsica (e.g. Vacchi et al., 2017; Revelles et al., 408 2019) and in Sardinia (Melis et al., 2017, 2018). However, the absence of fossil faunal associations 409 hampered a detailed reconstruction of the nature of this backshore environment and its millennial 410 evolution.
- 411 The lower part of the record (~6100 to ~4800 cal. BP) is characterized by high frequencies of 412 Spiniferites sp. (Fig. 7), dinoflagellate cysts often difficult to identify at the species level by routine 413 observation in light microscopy (de Vernal et al 2018). The genus Spiniferites is characterized by 414 marine species, but it cannot be excluded that some Mediterranean species live in freshwater 415 environments (Kouli et al., 2001; Zonneveld et al., 2013). Based on pollen records obtained from 416 central Mediterranean regions, the presence of *Spiniferites* is often associated to brackish water (Di 417 Rita et al., 2018b). Irrespective of water salinity, high frequencies of *Spiniferites* in the lower part of 418 the Crovani sequence may reflect the pioneer stages of a hydrosere succession connected to the early 419 phases of development of the coastal pond.
- From ~4800 to ~3350 cal. BP (zone CRO-2), a significant increase in *Ruppia maritima*, a submerged angiosperm with large salinity tolerance (Kantrud, 1991), coupled with occurrences of foraminiferal linings, highlights a brackish environment. It is consistent with the observed presence of halite in unit VI (Fig. 4). Beds of submerged usually occur on muddy sand and mud in brackish pools. They accumulate sediment and may be associated with terrestrial saltmarsh plants, forming a hydrosere succession in coastal wetlands (Rodwell, 2000).
- 426 Starting from ~3350 cal. BP, the abrupt decrease in *Ruppia* and the disappearance of most spores of 427 fungi, coupled with a major increase in *Pseudoschizaea* (2%) and fern spores, are the results of 428 complex sedimentological and ecological changes leading to a lowering of the water level and to the 429 establishment of the present-day marshy environments. *Pseudoschizaea* suggests both desiccation 430 (Scott, 1992) and freshwater flows accompanied by erosive processes, sometimes associated with
- 431 runoff events (Pantaléon-Cano et al., 2003), while the disappearance of most fungal spores, the

- decrease in pollen concentrations, and the high percentages of Cichorioideae (Figs 6-8) can be
  interpreted as selective preservation of palynomorphs (Bottema, 1975; Havinga, 1984).
- 434 It is noteworthy that Reille (1992a) recorded a sharp drop in Ruppia at 150 cm depth and correlated 435 it with a local change in sediment accumulation. This was caused by an event of forest clearance, 436 followed by an increase in runoff, leading to the accumulation of a sandy layer and a significant 437 development of ferns. In our record, a phase of increased terrestrial runoff is revealed by an input of 438 organic matter of continental origin recorded by a positive excursion of C/N ratio at 1.36 m (ca. 3250 439 cal. BP - Fig. 4) and by a significant increase in detrital minerals (Fig. S1), but is not preceded by 440 clear changes in AP percentages that may testify to a deforestation process, although there is a drop 441 in AP concentrations around 3350 cal. BP. A clearance of local shrubs, represented by a sharp decline 442 in *Erica* frequencies, was recorded only after ~3100 cal. BP (Figs 6 and 8).
- 443 Summarizing, initially the opening of the vegetation did not change the composition of the shrubland, 444 which was later affected by the drop of *Erica*. Sedimentological analyses indicate an increase of the 445 granulometry within a broader context of swamp environment of deposition characterized by 446 homogeneous clays. At ~136 cm depth (ca. 3250 cal. BP), there is an event of higher energy of 447 deposition characterized by the punctual presence of coarse silts to fine sands. In the Canniccia pond, 448 located in SW Corsica, Ghilardi et al. (2017b) and Vella et al. (2019) identified a high detrital input 449 dated ca. 3350 cal. BP. At a regional scale, the southern France recorded an intense phase of 450 alluviation within the Rhone drainage basin (Berger et al., 2007) and the Pyrenean mountains (Galop 451 et al., 2007).
- This is possibly explained by the occurrence of a cooler and more arid period that resulted in deforestation on a regional scale (Ghilardi et al., 2017a), recognized in western Mediterranean pollen records (Carrión, 2002; Fletcher et al., 2013) and in speleothems from Tuscany located only ca. 200 km from Crovani (Regattieri et al., 2014). However, the eastern coast of Corsica did not record such event (Currás et al., 2017), which seems to have especially affected western Corsica.
- 457 Since ~2900 cal. BP, an expansion of ferns and other hydrophytes (Fig. 7) suggests stagnant water, 458 which may have been produced by a lowering of the lake enhanced by runoff and a salinity change 459 towards more freshwater conditions. This change is confirmed by the observed decrease in the halite 460 since the final part of units VI (Fig. 4). Such pattern is consistent with a substantial sea-level stability, 461 which occurred in the NW Mediterranean Sea in the last ~2000 years (Vacchi et al., 2021). This 462 stabilization process significantly decreased the salinity input within the pond triggering the 463 progressive transition in pure freshwater environment.
- 464 Overall, the sequence dinoflagellates (*Spiniferites*)  $\rightarrow$  acquatic plants (*Ruppia maritima*)  $\rightarrow$  ferns 465 profiled throughout the pollen record corresponds to a hydrosere succession, whose evolution is

strictly related to the sediment infilling of lakes (Fig. 6). This ecological succession typically involves reed swamp vegetation at an intermediate stage, here represented by pollen of Cyperaceae and partly of Poaceae, and *Alnus* at a mature stage. In several coastal sedimentary archives of the central Mediterranean, temporary expansions of Cyperaceae and Poaceae are followed by an increase in *Alnus* (Magri et al., 2019 and references therein). At Crovani this pattern is especially clear in the interval between ~2600 and ~1700 cal. BP, when complete hydrosere succession with a climax woodland stage occurred in marginal sectors of the basin, in relation to a lagoon reduction (Fig. 6).

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#### 474 5.3. Human impact on the landscape

475 Human activity is evident throughout the pollen record with different intensity and type of land use

476 (Fig. 10). During the Late Neolithic, from ~3900 to ~3250 BC, the continuous curve of cereal-type

477 pollen testifies to early cultivations (Fig. 6). Evidence for agriculture is also observed at the Saint

478 Florent site starting from ~4000 cal. BC (Revelles et al., 2019), but only the extreme south of the

479 island (Bonifacio-Piantarella area) exhibits continuous agricultural practices all along the Neolithic

- 480 period. At Crovani, the pollen record reveals human activity older than the archaeological finds,
- indicating that farming was practiced ~1000 years before the earliest trace of human occupation at
  the Teghja di Linu site (Sicurani and Martinet, 2019).

483 Cereal cultivation appears associated to livestock rearing activities, which contributed to the 484 development of disturbed meadows, as highlighted by a significant record of Sporormiella, Sordaria, 485 and Podospora, and by pollen indicators for Mediterranean pasturelands, such as Carduus-type, 486 Plantago, Polygonum aviculare-type, as well as some species of the subfamilies Asteroideae and 487 Cichorioideae (Desprat et al., 2013; Florenzano et al., 2015) (Figs 6 and 8). The high values of 488 microcharcoal may partly reflect the use of fire for farming purposes, such as slash-and-burn 489 practices, which however did not affect the fire-adapted local shrubland. In general, human activity 490 during the Late Neolithic certainly influenced the vegetation evolution of the area, but its impact did 491 not produce a marked local deforestation. While we cannot advance any precise explanation for this 492 pattern, we can speculate that local settlements were not populated enough to produce forest declines 493 detectable in the pollen diagram.

494 During the Final Neolithic and Bronze Age (from ~3000 to ~800 BC), both cereal cultivation and 495 livestock rearing appear less intense and discontinuous. The archaeological history of Corsica 496 indicates that Early to Middle Bronze Age are periods of human implantation in the upper part of the 497 hills (Casteddi) when lowlands and coastal areas were less occupied (Cesari and Pêche Quilichini, 498 2015). The pollen record from Crovani confirms this pattern, even if in some coastal areas the Mid-499 to Late Bronze Age corresponds to a phase of renewed agriculture (Ghilardi et al., 2017a).

- In the Iron Age, cereals disappeared and scattered occurrences of pasture weeds (e.g., *Carduus*, *Plantago*, and *Rumex*) testify to poor farming practices addressed to livestock rearing, suggesting a
  scarce human frequentation in the area (Fig. 6).
- Human activity at Crovani is also revealed by the record of cultivated trees (OJCV curve, Fig. 8),
  which also include pollen of wild individuals of *Olea* and *Vitis* that is difficult to differentiate from
  pollen of cultivated plants (Reille, 1992a).
- 506 In the period encompassing the Neolithic to the Bronze Age the pollen record of Crovani shows some 507 early occurrences of Juglans (ca. 3700 BC) and Castanea (ca. 1200 BC) (Fig. 6). Similar early finds 508 are also recorded in pollen diagrams from recently published coastal sites (Poher et al., 2017; Currás 509 et al., 2017; Revelles et al., 2019). Although these occurrences are generally found during phases of 510 intense human activity, as confirmed by the presence of other anthropogenic pollen indicators, it is 511 difficult to hypothesize that cultivation of these trees was such early, without a clear archaeobotanical 512 evidence. Unfortunately, the palynological studies of Reille (1992a; 1999) and Lestienne (2020a) do 513 not contribute to solve this question, since their records do not show any Castanea and Juglans before 514 2500 cal. BP. They interpret these finds as a result of cultivation in the island in historical times. In 515 addition, the absence of palynological investigations from Pleistocene sediments prevents us to 516 speculate on a possible redeposition of pollen from older deposits. We would exclude a long-distance 517 origin, especially for Juglans, whose pollen dispersal occurs over short distance despite its renowned 518 anemophily (Carrión and Sánchez-Gómez, 1992).
- 519 Phylogeographical studies demonstrate that the post-glacial distribution of chestnut and walnut in 520 Europe and in the Mediterranean regions started from multiple glacial refugia (Mattioni et al., 2013; 521 Pollegioni et al., 2017). However, due to both the scarcity of palaeobotanical knowledge and 522 incomplete genetic sampling, as in the case of Corsica and Sardinia, there is still much uncertainty in 523 detecting glacial refugia and drawing up robust biogeographical histories of cultivated trees (Médail 524 et al., 2019).
- 525 In historical time, the OJCV record shows two major phases of tree cultivation. The first one, between 526 ~250 BC and ~150 AD, reflects a widespread exploitation of olive resources during the Roman 527 Period, also documented by archaeological evidence (Terral et al., 2004). The second increase, after 528 ~1450 AD, testifies to an intensification of *Olea* cultivation and a regional plantation of *Castanea* in the uplands. From 1548 until the 17th century, the Genoese Authority introduced the compulsory 529 530 cultivation of chestnut, whose fingerprint in the Crovani record is represented by a peak of Castanea 531 (Fig. 6) (Michon, 2011). The consequence of this decree was a large reorganization of the food, 532 economy, and socio-cultural systems, as shepherds slowly became chestnut growers and settled more permanently in mid-mountain villages. The chestnut culture fully developed during the 18th and 19th 533

534 centuries, providing flour for daily meals, fodder for animals, and fruits for trade. By the end of the 535 19<sup>th</sup> century, the development of local industries and the related outflow of rural population toward 536 urban centres determined the collapse of the chestnut culture (Michon, 2011).

537 Human impact on the forest cover is recorded since ~1000 BC (Final Bronze Age), mostly by 538 decreases in evergreen trees and shrubs staggered over time (Fig. 8), coupled with increases in both 539 herbaceous vegetation and *Cistus* dominated low shrublands (Figs 6 and 8). Considering the local 540 modest farming practices of the last three millennia, this pattern may mostly reflect clearance 541 practices of the Erica shrubland at a regional scale. This is consistent with the human-induced 542 opening of the forests recorded in several other pollen sites of Corsica (Reille, 1992a; Revelles et al., 543 2019; Lestienne et al., 2020a), and in coastal sites of the central Mediterranean since ~1000 cal. BC 544 (Di Rita and Magri, 2012). According to Roberts et al. (2019), after ~1000 BC human activity became 545 the dominant causation in determining landscape openings in the Mediterranean regions

546 Despite clear land use changes are recorded, human activities at Crovani did not completely transform the structure of the vegetation in terms of forest canopy, except for a temporary dramatic drop of the 547 548 maquis vegetation between 950 and 1450 AD (1000-500 cal. BP), for which a prominent 549 anthropogenic causation cannot be ruled out. Pollen indicators of human activity are scarce in this 550 period, but the reappearance of coprophilous fungi (Sporormiella) and the increase in Castanea and 551 Olea, together with a slight increase in fire frequency, may reflect silvicultural practices addressed to 552 the felling of shrublands to gain land available for both stock rearing and olive cultivation in the 553 lowlands, as well as for chestnut cultivation in the uplands. A similar observation was advanced in 554 the Saint-Florent area, where an important deforestation phase was coeval to the development of 555 pastoral activities (Revelles et al., 2019). Between ~1000 and ~500 cal. BP, also frequencies >2% of 556 *Pseudoschizaea* and *Glomus* support soil erosion and local deforestation (Figs 7 and 10). This was 557 also the time when several churches were locally built (Fig. 1A).

The human activities may also be tracked from the Pb isotope signature of the Crovani sediments. The sedimentary Pb data are aligned along a linear trend in a binary <sup>208</sup>Pb/<sup>206</sup>Pb - <sup>206</sup>Pb/<sup>207</sup>Pb diagram (Fig. 5A and B). Such distribution indicates a mixing between two end-members, a natural endmember with higher isotope Pb ratios and a probable anthropogenic-derived end-member characterised by lower isotope ratios.

(a) The first end-member has been defined by the average signature of 3 samples dated from the Final Neolithic period (196 to 260 cm). They are used to define the local detrital source with low isotopes ratios (i.e.,  ${}^{208}\text{Pb}/{}^{204}\text{Pb} = 38.9584 \pm 0.0020$ ,  ${}^{207}\text{Pb}/{}^{204}\text{Pb} = {}^{206}\text{Pb}/{}^{204}\text{Pb}$  15,6719 ± 0.0008 and  ${}^{206}\text{Pb}/{}^{204}\text{Pb} = 19,0775 \pm 0.0008$ ) (Table S1). This end-member represents the natural background endmember. There is no significant difference between the Final Bronze age and Final Neolithic and the

Bronze Age signatures. The composition of the samples corresponding to the Iron age, only defined 568 569 by 2 measurements, is slightly different from the previous Bronze and Final Neolithic periods, with 570 a position closer to the sample from the Roman representative average. The Pb isotope ratios of the 571 sediments roughly decrease upwards from the natural background end-member. The oldest pre-572 Roman samples (n= 19, 93-260 cm) are clustered with an average signature of  $38.9667 \pm 0.0235$ ,  $15.6716 \pm 0.0007$  and  $19.0702 \pm 0.0008$  for  ${}^{208}\text{Pb}/{}^{204}\text{Pb}$ ,  ${}^{207}\text{Pb}/{}^{204}\text{Pb}$  and  ${}^{206}\text{Pb}/{}^{204}\text{Pb}$ , respectively. 573 574 Note there is no significant difference in the Pb signature between the Bronze Age samples (106-186 cm) and the Iron age samples (measured at 93 and 99 cm) (Fig. 5 and Table S1). 575

- 576 (b) A shift towards lower Pb isotope ratios is marked for the Roman samples (53 and 73 cm) and 577 for the modern samples (11-23 cm). The first Roman shift may be related to some exploitation of Pb 578 ores. The isotope composition of both regional Pb-bearing ores and modern urban airborne particles 579 (Bollhöfer and Rosman, 2001) are reported in order to confirm any anthropogenic contribution in the 580 sediment Pb isotope composition. The isotope Pb ratios of the Roman and modern samples become 581 closer and closer to the Corsican Pb minerals (Fig. 5). The analysed Pb-bearing minerals display close Pb isotope signatures, with an average composition of 1.1779 for <sup>206</sup>Pb/<sup>207</sup>Pb and 2.0894 for 582 583 <sup>208</sup>Pb/<sup>206</sup>Pb. The first decrease of the Pb isotopic ratio observed in the Roman Crovani sediments is 584 in agreement with the historical exploitation of the Pb-Ag ores from the Argentella during the Roman 585 period (Gauthier, 2006). The linear trend defined by the modern samples does not point towards the 586 modern urban airborne particles but rather towards the Pb signature of the Sardinian ores (Stos-Gale 587 et al., 1995). In the Crovani sediments, Sardinia seems to be the most probable anthropogenic source 588 of Pb among the main Pb mines exploited in the Mediterranean area, i.e. in Greece, Turkey, Italy and Spain since the Antiquity (see more details in Fagel et al., 2017). In the binary <sup>206</sup>Pb/<sup>207</sup>Pb-<sup>208</sup>Pb/<sup>206</sup>Pb 589 590 diagram, the Crovani samples define a linear trend that, if extrapolated, points to the representative 591 average signature of Sardinian ores (Fig. 5 B).
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#### 593 5.4. Effects of Rapid Climate Changes on the coastal tree-cover

In the palaeobotanical narrative of Corsica, no clear tree-cover change has ever been attributed to a "Bond event" (Bond et al., 2001) (Fig. 8) or other RCC of global interest, such as the 4.2 ka event (Bini et al., 2019), the Homeric minimum (2.8 ka BP) (Martin-Puertas et al., 2012) and the Little Ice Age (Trouet et al., 2009). These events have produced major changes in forest cover in many sites of

598 central and western Mediterranean regions, although with contrasting trends (Fletcher et al., 2013,

599 Magny et al., 2013; Di Rita et al., 2018a).

The 4.2 cal. BP event, perceived in south-central Italy as an aridity crisis producing a forest decline,did not trigger a rapid response in the regional forest vegetation in Corsica and in the northern

- 602 Apennines (Di Rita and Magri, 2019; Revelles et al., 2019; Di Rita et al., 2022). However, previous 603 studies in Corsica have shown that the 4.2 event played an influence on geomorphological and 604 sedimentological processes, due to increased storm and fluvial activities as recorded in several lagoon 605 archives (Revelles et al., 2019 and references therein). In our record from Crovani, rapid fluctuations 606 of the forest cover are found, marked by maximum values of AP (92%) at ca. 4450 cal. BP (Figs 6 607 and 8). Between 4700 and 3500 cal. BP, a long-lasting increase in Fagus suggests permanent humid 608 conditions during the Mid- to Late Holocene transition (Fig. 6), which are recorded also in other 609 montane (Reille, 1975; Reille et al., 1999) and pollen sequences from coastal Corsica (Poher et al., 610 2017; Revelles at al., 2019). The development of beech corresponds to relatively wet climatic 611 conditions in central Italy, as revealed by lake level highstands at Lake Accesa ca. 160 km far from 612 Crovani (Magny et al., 2013). Lake level highstands reflecting humid conditions are also recorded in 613 northern Italy (cf. Lake Ledro: Magny et al., 2012), and in west-central Europe (Magny et al., 2013) 614 and references therein).
- The development of beech corresponds also to periods of increased storm activity in southern France (Sabatier et al., 2012) (Fig. 8). Although these periods were previously interpreted as the result of southward westerly winds bringing moisture to mid-latitudes in Europe (Sabatier et al., 2012; Magny et al., 2013), they may also reflect an increase in the frequency of marine storms that are not directly interpretable as periods of regional increased precipitation (Azuara et al., 2020). An alkenone record from the Gulf of Lion suggests moisture increase in southern France since ca. 4200 cal. BP (Jalali et al., 2017; Azuara et al., 2020).,
- The general pattern of increased humidity in western Corsica contrasts with the drier conditions indicated by precipitation proxies from the speleothems of the Corchia and Renella caves in Tuscany (Zanchetta et al., 2016; Isola et al., 2019), and depicts a complex geographic expression of the 4.2 ka event (Bini et al., 2019; Di Rita and Magri, 2019; Di Rita et al., 2022).
- 626 The Homeric Minimum (2750-2550 cal. BP, Martin-Puertas et al., 2012) was associated to forest 627 declines influenced by human impact and dryer climate conditions in many records of the southcentral Mediterranean (Di Rita et al., 2018c). At Crovani, it corresponds to a modest peak in AP, 628 629 possibly related to slightly wetter conditions. Relatively higher precipitations were recorded from 630 lake-level highstands since 2800 cal. BP at Lake Accesa (Fig 8), and from lake-level highstands and pollen evidence at Lake Ledro (Magny et al., 2012; Peyron et al., 2017). More humid climate 631 632 conditions were also found in the western Mediterranean, possibly associated to the negative NAO 633 index that characterizes this interval (Fletcher et al., 2013). This phase corresponds also to increased
- 634 storm activity in the Gulf of Lion (Sabatier et al., 2012).

- 635 During the Little Ice Age, the record of Crovani shows a marked increase in *Erica* and *Q. ilex maquis*,
- accompanied by significant frequencies of cultivated trees related to orchards and conifer plantations
- 637 (Figs 6 and 8). The development of natural and cultivated woody taxa was probably favoured by
- relatively wet climate conditions, which were also recorded in both central and northern Italy from
- 639 lake-level highstands (Magny et al., 2013), as well as in southern France from records of major
- 640 flooding (Benito et al., 2015, Pichard et al., 2017), coinciding with a mostly negative NAO index
- 641 (Franke et al., 2017) (Figs 8 and 10). Climate reconstructions in Corsica are still fragmentary,
- 642 however the few published studies indicate the occurrence of periods characterized by wet and cool
- 643 conditions (Szymczak et al., 2012; Vella et al., 2014).
- 644 The archaeological and paleoenvironmental literature does not provide noticeable examples of rapid 645 and dry climate events in Corsica. As previously discussed, the complex sedimentological pattern at 646 ~3250. cal. BP (Fig. 4) might be related to an arid climate event observed around the same age in 647 other palaeoenvironmental records. Relatively dry and warm climate conditions may have also 648 contributed to produce the major forest decline recorded between 1000 and 500 cal. BP, limiting the 649 resprout of the natural forest vegetation affected by felling activities. In the western Mediterranean, 650 the dry and warm climate of the Medieval Climate Anomaly is usually associated to an overall 651 positive NAO index (Trouet et al., 2009; Franke et al., 2017) (Fig. 8).
- Sabatier et al. (2020) have found a strong relationship between the transport of Saharan dust conveyed to Corsica during the last ~3000 years and both total solar irradiance (TSI) and NAO activity. They have shown that the NAO was the main climatic forcing for centennial to decadal variations since ~1070 AD, with an increase in Saharan dust input during positive NAO phases. Before ~1070 AD, TSI was the main forcing factor, with increases in African dust input during low TSI phases.
- 657 We applied a REDFIT analysis to the total AP percentages to investigate the effects of the 658 atmospheric circulation on the tree cover record from Crovani (Fig. 9). The prominent 230-year cycle 659 found in our statistical elaboration by and large corresponds to the Suess-de Vries cycle of solar 660 activity, which has been held responsible for environmental and atmospheric changes in several records around the world, including the Mediterranean (Castagnoli et al., 1992; Galloway et al., 2013; 661 662 Di Rita, 2013; Degeai et al., 2014; Sabatier et al., 2020). The Suess-de Vries cycle is commonly 663 identified as a conventional 210-year periodicity; however, an increasing number of studies 664 demonstrates its non-stationary variability, which may have a range of ~200-300 years (Vecchio et 665 al., 2017). Similarly, its expression in palaeoenvironment proxies shows a non-stationary periodicity
- 666 (Galloway et al., 2013). A 230-year cycle was detected in direct proxies of solar magnetic activity,
- such as <sup>14</sup>C time series and naked-eye observations of sunspots (Ma and Vaquero, 2020).

The REDFIT analysis from Crovani shows also two periodicities of ca. 430 and 1000 years, 668 669 respectively (Fig. 9). The first one corresponds to the ca. 430-years and 450-year cycles detected by 670 Sabatier et al. (2020) in the records of Saharan dust in Corsica, as shown by both TSI and ITCZ, 671 although the authors attribute a low significance to this cycle. A 440-year cycle (together with a 230year cycle) was found in  $\delta^{13}$ C records of speleothems from northern Iberia and was interpreted as the 672 result of climate forcing mechanisms related to changes in solar irradiance and North Atlantic 673 674 circulation patterns (Mártin-Chivelet et al., 2011). Periodicities of ~400-years were recognized in 675 various palaeoclimate proxies from both marine (e.g., Bond et al., 2001) and lake records (e.g., Yu

and Ito, 2002; Wu et al., 2009) of the Middle-Late Holocene.

The last periodicity we found at Crovani matches a prominent ~1000-year cycle of moisture supply reported in proxy records from the western Mediterranean, especially during the Early Holocene, which have been associated to solar activity (Debret et al., 2009; Fletcher et al., 2013; Jiménez Moreno et al., 2020 and references therein).

681 Overall, our results show that the forest oscillations at Crovani present a fundamental tempo of 682 variability consistent with the atmospheric forcing held responsible for the transport of Saharan dust 683 to Corsica. Although the relationship between solar activity and forest dynamics in Corsica is only 684 sketched, our findings encourage future research in the central Mediterranean, interpreted in the light 685 of the regional patterns of vegetation change.

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#### 687 5.5. Coastal landscape evolution of the Crovani area

688 Based on the cross combination of sedimentological, palynological and geochemical proxies, we 689 propose a synthetic palaeogeographical reconstruction of the investigated area, even if additional 690 cores would be necessary to evaluate in a comprehensive way both the morphological changes and 691 the spatial evolution of the Crovani wetland since the Mid-Holocene. The bottom of the core records 692 a detrital environment with a mixture of well-rounded pebbles and coarse material, ranging from 693 sands to gravels. Unfortunately, this section of the core did not contain enough organic material for 694 obtaining a radiocarbon age. Furthermore, facies identification was difficult due to the lack of fossil 695 fauna. However, on the basis of the sedimentological information, two types of energy of deposition 696 can be identified. The first is controlled by terrestrial dynamics being characterized by the finest 697 particles (grey clays). The second is conversely controlled by coastal dynamics as indicated by the 698 presence of well-rounded pebbles that are analogue in shape and petrography to the sediments which 699 compose the modern coastal barrier. These data suggest that the continental dynamics likely prevailed 700 during the first half of the Holocene. This was followed by a mid-Holocene marine transgression that 701 reached its maximum ~6500 cal. BP, when the sea-level in Corsica was ca. 3.5 to 4 m below the

702 present-day position (Vacchi et al., 2018). At that time, which broadly correspond to Middle to Late 703 Neolithic, a marine incursion occurred in the Crovani coastal pond following a pattern that was also 704 observed in other coastal lagoons in Corsica, such as Saint Florent (Revelles et al., 2019) and Del 705 Sale (Curras et al., 2017). As a result, the pond turned into brackish conditions after ~6100 cal. BP, 706 as confirmed by the presence of Spiniferites, which substantially indicates a connection with the sea 707 (Fig. 6 and 10). However, probably due to the presence of Late Pleistocene alluvial formations and 708 relict coastal deposits (former coastal barriers), the marine incursion inland was spatially limited. This 709 could explain the lack of faunal assemblages typical of coastal lagoon made by ostracods, 710 foraminifera and molluscs faunas. After ~5100 cal. BP, during the Late to Final Neolithic 711 characterized by the first occupation of the nearby site of Teghja di Linu, data show detrital input that 712 suddenly modified the brackish conditions on the pond. However, our data indicates that nor a climate 713 event neither human impact provoked deforestation associated to intense erosion on the foothills and 714 sedimentary accumulation of coarse material, even if there is a clear land-use at that time (Fig. 10). 715 A second phase of wetland development is well attested from the Final Neolithic to Middle/Recent 716 Bronze Age. Presence of salt intrusion is confirmed by both the vegetation composition and the 717 geochemical analyses (presence of halite) but there is no clear evidence for a direct of the coastal 718 pond connection to the sea (e.g., presence of faunal assemblages typical of coastal lagoons). A second 719 detrital input is observed during the Late Bronze Age (Unit VII). The C/N Ratio exhibits the highest 720 values for the entire sequence studied, thus indicating a terrestrial deposition of organic matter (see 721 section 4.2.) (Fig. 4). This is likely a rapid event (not more than a century in duration) that could have 722 caused the silting up of the wetland. Finally, the present-day landscape configuration is established 723 since Final Bronze Age (unit VIII) with very little morphological changes afterwards. Since ~3200 724 cal. BP, Crovani coastal pond has been a backshore freshwater body with probable aeolian input of 725 salt, no permanent connection to the sea, and low sediment accumulation rate (Fig. 10).

726 727

#### 728 6. Conclusions

The new multidisciplinary dataset obtained from northwest Corsica helps to reconstruct the past environmental dynamics (Fig. 10) within an archaeological context, and to frame it into the wider scenario of the central Mediterranean landscape evolution. Our results contribute to the lively discussion on the vegetation response to rapid climate changes, raising also new questions about planetary drivers of past atmospheric circulation and their possible influence on the forested ecosystems of this strategic region of the Mediterranean. In particular, the following conclusions can be traced: 1) A dense *Erica*-dominated shrubland rich in many evergreen elements characterized the landscape from ~6100 to ~1000 cal. BP, being temporarily replaced by mixed woodlands dominated by *Q. ilex* between 2300 and 1900 cal. BP. A major opening of the landscape occurred only between ~1000 and ~500 cal. BP, featured by a temporary decline in *Erica*-dominated tall shrublands, paralleled by an expansion of *Cistus*-dominated low shrublands and followed by the recovery of the tall *maquis* formations.

742 2) Fires played a prominent role in the development and maintenance of the *Erica*-dominated
743 shrublands, especially during the Middle Holocene (from ~5900 to ~5200 cal. BP), when frequent
744 and intense wild and anthropogenic fires boosted the sprout of *Erica* species. Differently from
745 other sites in Corsica and Sardinia, at Crovani fires did not affect *Q. ilex*, whose development
746 cannot be univocally explained in the region and may be influenced by a long-lasting ecological
747 legacy. The general decrease of fires after ~3300 cal. BP may reflect a combination of decreased
748 human activity and climate unsuitable for fires.

749 3) The Crovani wetland has been little influenced by marine incursions over the last six 750 millennia, as indicated by sedimentological data, pollen and NPPs. Moderate brackish conditions 751 occurred only from the Late Neolithic to part of the Bronze Age, while during the last three 752 millennia general freshwater conditions prevailed. The sequential development of dinoflagellates, 753 Ruppia, and ferns appears to reflect a hydrosere succession, whose evolution is strictly related to 754 the infilling of the lake. After ~3300 cal. BP, this ecological process was influenced by a sudden 755 deposition of continental organic-rich sediments, following rapid deforestation and runoff of 756 regional extension, coeval to an arid climate event occurred around ~3200 cal. BP.

757 4) Evidence for human activity is present throughout the pollen record, with important 758 differences through time. Between ~6000 and ~5200 cal. BP, a continuous curve of cereal-type 759 pollen testifies to the earliest cultivations in this area. Farming activities are also confirmed by the 760 presence of disturbed meadows for livestock rearing, indicated by coprophilous fungi and pollen 761 indicators of plants frequently living in Mediterranean pasturelands. Starting around 3300 cal. BP, 762 indicators of cereal cultivation and stock rearing practices became sparse, and evidence for human 763 activity comes from cultivated trees, especially after ca. 2000 cal. BP and even more after ~500 764 cal. BP. The former increase reflects olive exploitation during the Roman Period, the latter points 765 to both olive cultivation in lowland areas and chestnut culture in the uplands. A clear forest 766 degradation dates back to the last three millennia, with a dramatic opening of the landscape only from ~1000 to ~500 cal. BP, related to human activity in the medieval times and Genovese 767 768 domination.

769 5) The spectral analysis applied to total AP revealed a ~230-year cycle, in the bandwidth of the 770 Suess-de Vries cycle, and other cyclicities attributed to the magnetic activity of the Sun, 771 recognized also in other climate proxies from the Mediterranean. This suggests that the 772 atmospheric modifications of solar activity and North Atlantic Oscillation had some influence on 773 the tree cover fluctuations in Corsica. However, known rapid climate changes, such as the 4.2 ka 774 BP event, the Homeric minimum, and the Little Ice Age, did not determine at Crovani extensive 775 forest declines as they did in sites of the south-central Mediterranean. In contrast, in northwestern 776 Corsica these phases correspond to a forest development consistent with the humid phases detected 777 in southern France and northern Italy. The high-resolution record from Crovani is an important 778 piece of information to define the spatial pattern of vegetation response to the atmospheric 779 arrangements produced by rapid climate changes over the Mediterranean Basin during the 780 Holocene.

- 781
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- 793 **Reference list**
- 795 Azuara, J., Sabatier, P., Lebreton, V., Jalali, B., Sicre, M.-A., Dezileau, L., Bassetti, M.-A., Frigola, 796 J., Combourieu-Nebout, N., 2020. Mid- to Late-Holocene Mediterranean climate variability: 797 contribution of multi-proxy and multi-sequence comparison using wavelet spectral analysis 798 the northwestern Mediterranean basin. Earth Sci. Rev. 208, 103232. in 799 https://doi.org/10.1016/j.earscirev.2020.103232.
- Beffa, G., Pedrotta, T., Colombaroli, D., Henne, P.D., van Leeuwen, J.F.N., Süsstrunk, P.,
  Kaltenrieder, P., Adolf, C., Vogel, H., Pasta, S., Anselmetti, F.S., Gobet, E., Tinner, W., 2016.
  Vegetation and fire history of coastal north-eastern Sardinia (Italy) underchanging Holocene
  climates and land use. Veg. Hist. Archaeobotany 25, 271-289
- Bellotti, P., Calderoni, G., Di Rita, F., D'Orefice, M., D'Amico, C., Esu, D., Magri, D., Preite
  Martinez, M., Tortora, P., Valeri, P., 2011. The Tiber river delta plain (central Italy): coastal
  evolution and implications for the ancient Roman Ostia settlement. Holocene 21, 1105-1116.
- Benito, G., Macklin, M. G., Zielhofer, C., Jones, A. F., Machado, M. J., 2015. Holocene flooding and
  climate change in the Mediterranean. Catena 130, 13-33.
- Bengtsson, L., Enell, M., 1986. Chemical analysis, in: Berglund, B. E. (ed.), Handbook of Holocene
   Palaeoecology and Palaeohydrology. John Wiley & Sons Ldt., Chichester, 423–451.
- 811 Bennett, K., 2009. "psimpoll" and "pscomb": CPrograms for Analysing Pollen Data and Plotting
  812 Pollen Diagrams (Version 4.27). Available online from Queen's University Quaternary
  813 Geology program at URL. http://www.chrono.qub.ac.uk/psimpoll/psimpoll.html.
- Berger, J.F., Brochier, J.L., Vital, J., Delhon, C., Thiebault, S., 2007. Nouveau regard sur la dynamique des paysages et l'occupation humaine à l'Âge du bronze en moyenne vallée du Rhône, in: Mordant C., Richard H., Magny M. (Eds.), Environnements et cultures à l'âge du Bronze en Europe occidentale. Actes du 129e colloque du CTHS, Besançon, avril 2004, Editions du CTHS, Documents Préhistoriques 21, 260-283.
- Beug, H., 2004. Leitfaden der Pollenbestimmung für Mitteleuropaund angrenzende Gebiete. Verlag
   Dr. Friederich Pfeil, München.
- Bini, M., Zanchetta, G., Perşoiu, A., Cartier, R., Català, A., Cacho, I., Dean, J.R., Di Rita, F.,
  Drysdale, R.N., Finnè, M., Isola, I., Jalali, B., Lirer, F., Magri, D., Masi, A., Marks, L.,
  Mercuri, A.M., Peyron, O., Sadori, L., Sicre, M.-A., Welc, F., Zielhofer, C., Brisset, E., 2019.
  The 4.2 ka BP Event in the Mediterranean region: an overview. Clim. Past 15, 555-577.
- Birks, H.J.B., Line, J.M., 1992. The use of rarefaction analysis for estimating palynological richness
   from Quaternary pollen-analytical data. The Holocene 2, 1-10.
- Blaauw, M., Christen, J. A., 2011. Flexible paleoclimate age-depth models using an autoregressive
  gamma process. Bayesian analysis 6, 457-474.
- Bollhöfer, A., Rosman, K.J.R., 2001. Isotopic source signature for atmospheric lead: the Northern
  Hemisphere. Geochim. Cosmochim. Acta 65, 1727-1740.
- Bond, G., Kromer, B., Beer, J., Muscheler, R., Evans, M.N., Showers, W., Hoffmann, S., Lotti-Bond,
  R., Hajdas, I., Bonani, G., 2001. Persistent solar influence on North Atlantic climate during
  the Holocene. Science 294, 2130-2136.
- Bottema, S., 1975. The interpretation of pollen spectra fromprehistoric settlements (with special attention to Liguliflorae). Palaeohistoria 17, 17-35.
- Carcaillet, C., Barakat, H. N., Panaïotis, C., Loisel, R., 1997. Fire and late-Holocene expansion of
   *Quercus ilex* and *Pinus pinaster* on Corsica. J. Veg. Sci. 8, 85-94.
- Carrión, J.S., 2002. Patterns and processes of Late Quaternary environmental change in a montane
   region of southwestern Europe. Quaternary Sci. Rev. 21, 2047-2066.
- Carrión, J.S., Sánchez-Gómez, P., 1992. Palynological data in support of the survival of walnut
  (*Juglans regia* L.) in the western Mediterranean area during last glacial times. J. Biogeogr.
  19, 623-630.

- Carrión, J.S., Parra, I., Navarro, C., Munuera, M., 2000. Past distribution and ecology of the cork oak
   (*Quercus suber*) in the Iberian Peninsula: a pollen-analytical approach. Divers. Distrib. 6, 29 44.
- Castagnoli, G.C., Bonino, G., Serio, M., Sonnett, C.P., 1992. Common spectral features in the 5500year record of total carbonate in sea sediments and radiocarbon in tree rings. Radiocarbon 34,
  798–805.
- Caudullo, G., Tinner, W., de Rigo, D., 2016. *Picea abies* in Europe: distribution, habitat, usage and threats. In: San-Miguel-Ayanz, J., de Rigo, D., Caudullo, G., Houston Durrant, T., Mauri, A. (Eds.), European Atlas of Forest Tree Species. Publications Office of the European Union, Luxembourg e012300b
- 853 Cesari, J., Pêche-Quilichini, K., 2015. L'âge du Bronze corse. L'émergence d'une élite guerrière, in
  854 Leandri F., Istria D. (coord.), Corse, richesses archéologiques de la Préhistoire à l'époque
  855 moderne. Dossiers d'archéologie, 370, 24-29
- Clark, R.L., 1982. Point count estimation of charcoal in pollen preparations and thin sections of
   sediments. Pollen Spores 24, 523–535.
- Colombaroli, D., Tinner, W., Leeuwen, J. van, Noti, R., Vescovi, E., Vanniere, B., Magny, M.,
  Schmidt, R., Bugmann, H., 2009. Response of broadleaved evergreen Mediterranean forest
  vegetation to fire disturbance during the Holocene: in-sights from the peri-Adriatic region. J.
  Biogeogr. 36, 314-326.
- Cook, H.E., Johnson, P.D., Matti, J.C., Zemmels, I., 1975. Methods of sample preparation and X-ray
   diffraction analysis in X-ray mineralogy laboratory, in: Kaneps, A.G., et al. (Eds.), Init. Repts
   DSDP XXVIII. Print. Office, Washington DC, pp. 997-1007.
- Cugny, C., Mazier, F., Galop, D., 2010. Modern and fossil non-pollen palynomorphs from the Basque
   mountains (western Pyrenees, France): the use of coprophilous fungi to reconstruct pastoral
   activity. Veg. Hist. Archaeobot. 19, 391–408.
- 868 Currás, A., Ghilardi, M., Peche-Quilichini, K., Fagel, N., Vacchi, M., Delanghe, D., Contreras, D.,
  869 Vella, C., Ottaviani, J.C., 2017. Reconstructing past landscapes of the eastern plain of Corsica
  870 (NW Mediterranean) during the last 6000 years based on molluscan, sedimentological and
  871 palynological analyses. J. Archaeol. Sci.: Report 12, 755-769.
- b'Anna, A., Marchesi, H., Tramoni, P., Gilabert, C., Demouche, F., 2001. Renaghju (Sartène, Corsedu-Sud), un habitat de plein-air néolithique ancien en Corse. Bulletin de la Société préhistorique française 98, 431-444.
- Bean, W.E. Jr., 1974. Determination of carbonate and organic matter in calcareous sediments and
   sedimentary rocks by loss on ignition: Comparison with other methods. J. Sed. Petrol. 44:
   242–248
- Bebret, M., Sebag, D., Crosta, X., Massei, N., Petit, J.R., Chapron, E., Bout-Roumazeilles, V., 2009.
  Evidence from wavelet analysis for a mid-Holocene transition in global climate forcing. Quat.
  Sci. Rev. 28, 2675-2688.
- Begeai, J.P., Devillers, B., Dezileau, L., Oueslati, H., Bony, G., 2015. Major storm periods and
  climate forcing in the Western Mediterranean during the Late Holocene. Quaternary Sci. Rev.
  129, 37-56.
- Besprat, S., Combourieu-Nebout, N., Essallami, L., Sicre, M.A., Dormoy, I., Peyron, O., Siani, G.,
  Bout Roumazeilles, V., Turon, J.L., 2013. Deglacial and Holocene vegetation and climatic
  changes in the southern Central Mediterranean from a direct landesea correlation. Clim. Past
  9, 767-787.
- de Vernal, A., Eynaud, F., Henry, M., Limoges, A., Londeix, L., Matthiessen, J., Marret, F.,
  Pospelova, V., Radi, T., Rochon, A., Van Nieuwenhove, N., Zaragosi, S., 2018. Distribution
  and (palaeo)ecological affinities of the main *Spiniferites* taxa in the mid–high latitudes of the
  Northern Hemisphere. Palynology 42, 182–202.
- Bi Rita, F., 2013. A possible solar pacemaker for Holocene fluctuations of a saltmarsh in southern
  Italy. Quatern. Int. 288, 239-248.

- Bi Rita, F., Magri, D., 2012. An overview of the Holocene vegetation history from the central
   Mediterranean coasts. J. Mediterr. Earth Sci. 4, 35-52.
- Bi Rita, F., Magri, D., 2019. The 4.2 ka event in the vegetation record of the central Mediterranean.
   Clim. Past 15, 237-251.
- Bi Rita, F., Melis, R.T., 2013. The cultural landscape near the ancient city of Tharros (central West
   Sardinia): vegetation changes and human impact. J. Archaeol. Sci. 40, 4271-4282.
- Di Rita, F., Fletcher, W. J., Aranbarri, J., Margaritelli, G., Lirer, F., Magri, D., 2018a. Holocene forest
   dynamics in central and western Mediterranean: periodicity, spatio-temporal patterns and
   climate influence. Scientific Reports 8, 8929.
- Di Rita, F., Molisso, F., Sacchi, M., 2018b. Late Holocene environmental dynamics, vegetation
   history, human impact, and climate change in the ancient *Literna Palus* (Lago Patria;
   Campania, Italy). Rev. Palaeobot. Palyno. 258, 48-61.
- Di Rita, F., Lirer, F., Bonomo, S., Cascella, A., Ferraro, L., Florindo, F., Insinga, D.D., Lurcock, P.C.,
  Margaritelli, G., Petrosino, P., Rettori, R., Vallefuoco, M., Magri, D., 2018c. Late Holocene
  forest dynamics in the Gulf of Gaeta (central Mediterranean) in relation to NAO variability
  and human impact. Quaternary Sci. Rev. 179, 137–152.
- Di Rita, F., Michelangeli, F., Celant, A., Magri, D., 2022. Sign-switching ecological changes in the
   Mediterranean Basin at 4.2 ka BP. Global Planet. Change 208, 103713.
- Fagel, N., Lechenault, M., Fontaine, N., Pleuger, E., Otten, J., Allan, M., Ghilardi, M., Mattielli, N.,
  Goiran, J-P., 2017. Record of human activities in the Pb isotopes signatures of coastal
  sediments from the Roman archaeological site of Cala Francese, Cape Corsica (France). J.
  Archaeol. Sci.: Reports 12, 770-781.
- Fletcher, W.J., Debret, M., Goñi, M.F.S., 2013. Mid-Holocene emergence of a low-frequency
  millennial oscillation in western Mediterranean climate: Implications for past dynamics of the
  North Atlantic atmospheric westerlies. The Holocene, 23, 153-166.
- Florenzano, A., Marignani, M., Rosati, L., Fascetti, S., Mercuri, A.M., 2015. Are Cichorieae an indicator of open habitats and pastoralism in current and past vegetation studies? Plant Biosyst. 149, 154-165.
- Franke, J.G., Werner, J.P., Donner, R.V., 2017. Reconstructing Late Holocene North Atlantic
   atmospheric circulation changes using functional paleoclimate networks. Clim. Past 13, 1593 1608.
- Galloway, J.M., Wigston, A., Patterson, R.T., Swindles, G.T., Reinhardt, E., Roe, H.M., 2013.
  Climate change and decadal to centennial-scale periodicities recorded in a late Holocene NE
  Pacific marine record: Examining the role of solar forcing. Palaeogeography,
  Palaeoclimatology, Palaeoecology 386, 669-689.
- Galop, D., Carozza, L., Marembert, F., Bal, M.C., 2007. Activités agropastorales et climat durant
  l'Âge du Bronze dans les Pyrénées : l'état de la question à la lumière des données
  environnementales et archéologiques, in: Mordant C., Richard H., Magny M. (Eds.),
  Environnements et cultures à l'âge du Bronze en Europe occidentale. Actes du 129e colloque
  du CTHS, Besançon, avril 2004, Editions du CTHS, Documents Préhistoriques, 21, 107-119.
- Gauthier, A., 2006. Des roches, des paysages et des hommes. Géologie de la Corse, Ajaccio, Edition
   Albiana, France, 276 p.
- Gelorini, V., Verbeken, A., van Geel, B., Cocquyt, C., Verschuren, D., 2011. Modern non-pollen
  palynomorphs from East African lake sediments. Rev. Palaeobot. Palyno. 164, 143-173.
- Ghilardi, M., 2020. Lagunes et marais littoraux de Corse. De la Préhistoire à nos jours. Collec. Orma:
  la Corse archéologie, Editions ARAC, 5, 105 p.
- Ghilardi, M., 2021. Geoarchaeology: Where Geosciences Meet the Humanities to Reconstruct Past
   Human–Environment Interactions. An Application to the Coastal Areas of the Largest
   Mediterranean Islands. Appl. Sci. 11, 4480. https://doi.org/10.3390/app11104480
- Ghilardi, M., Istria, D., Currás, A., Vacchi, M., Contreras, D., Vella, C., Dussouillez, P., Crest, Y.,
  Colleu, M., Guiter, F., Delanghe, D., 2017a. Reconstructing the landscape evolution and the

- human occupation of the Lower Sagone River (Western Corsica, France) from the Bronze
  Age to the Medieval period, in: Ghilardi M. and Lespez L. (Eds.), Geoarchaeology of the
  Mediterranean islands. J. Archaeol. Sci.: Reports, 12, 741-754.
- Ghilardi, M., Delanghe, D., Demory, F., Leandri, F., Pêche-Quilichini, K., Vacchi, M., Vella, M.A.,
  Rossi, V., Robresco, S., 2017b. Enregistrements d'événements extrêmes et évolution des
  paysages dans les basses vallées fluviales du Taravo et du Sagone (Corse occidentale, France)
  au cours de l'âge du Bronze moyen à final: une perspective géoarchéologique.
  Géomorphologie, Relief, Processus et Environnement 23, 15-35.
- Grimm, E.C., 1987. CONISS: a FORTRAN 77 program for stratigraphically constrained cluster
   analysis by the method of incremental sum of squares. Computers & Geosciences 13, 13-35.
- Hammer, Ø., Harper, D.A.T., Ryan, P.D., 2001. PAST: paleontological Statistics software package
   for education and data analysis. Palaeontol. Electron. 4, 9.
- Havinga, A.J., 1984. A 20-year experimental investigation into the differential corrosion
  susceptibility of pollen and spores in various soil types. Pollen Spores 26, 541–58.
- Henry, A.G. (Ed.), 2020. Handbook for the Analysis of Micro-particles in Archaeological Samples.
   Springer International Publishing.
- Isola, I., Zanchetta, G., Drysdale, R.N., Regattieri, E., Bini, M., Bajo, P., Hellstrom, J.C., Baneschi,
  I., Lionello, P., Woodhead, J., 2019. The 4.2 ka event in the Central Mediterranean: new data
  from a Corchia speleothem (Apuan Alps, Central Italy). Clim. Past 15, 135–151.
- Jalali, B., Sicre, M.-A., Kallel, N., Azuara, J., Combourieu-Nebout, N., Bassetti, M.-A., Klein, V.,
  2017. High-resolution Holocene climate and hydrological variability from two major
  Mediterranean deltas (Nile and Rhone). The Holocene 27 (8), 1158–1168.
- Jeanmonod, D., Schlüssel, A., 2006. Notes and contributions on Corsican flora, XXI. Candollea, 61,
  968 93-134.
- Jiménez-Moreno, G., Anderson, R.S., Ramos-Román, M.J., Camuera, J., Mesa-Fernández, J.M.,
  García-Alix, A., Jiménez-Espejo, F.J., Carrión, J.S., López-Avilés, A., 2020. The Holocene *Cedrus* pollen record from Sierra Nevada (S Spain), a proxy for climate change in N Africa.
  Quaternary Sci. Rev. 242, 106468.
- Kantrud, H.A., 1991. Wigeongrass (Ruppia maritima L.): A Literature Review, vol. 10. U.S. Fish and
   Wildlife Service, Fish and Wildlife Research, 58 pp.
- Kouli, K., Brinkhuis, H., Dale, B., 2001. *Spiniferites cruciformis*: a fresh water dinoflagellate cyst?.
  Rev. Palaeobot. Palynolo 113, 273-286.
- Lestienne, M., Jouffroy-Bapicot, I., Leyssenne, D., Sabatier, P., Debret, M., Albertini, P. J.,
  Colombaroli, D., Didier, J., Hély, C., Vannière, B., 2020a. Fires and human activities as key
  factors in the high diversity of Corsican vegetation. The Holocene 30, 244-257.
- Lestienne, M., Hely, C., Curt, T., Jouffroy-Bapicot, I., Vannière, B., 2020b. Combining the Monthly
  Drought Code and Paleoecological Data to Assess Holocene Climate Impact on
  Mediterranean Fire Regime. Fire 3(2), 8.
- Leleu, F., 2021. Calenzana–Les mines de l'Argentella. Prospection thématique (2018). ADLFI.
  Archéologie de la France Informations [Online], Corse, Online since 08 January 2021,
  connection on 14 December 2021. URL: http://journals.openedition.org/adlfi/50226
- Leys, B., Carcaillet, C., Dezileau, L., Ali, A.A., Bradshaw, R.H., 2013. A comparison of charcoal measurements for reconstruction of Mediterranean paleo-fire frequency in the mountains of Corsica. Quaternary Res. 79, 337-349.
- Leys, B., Finsinger, W., Carcaillet, C., 2014. Historical range of fire frequency is not the Achilles'
  heel of the Corsican black pine ecosystem. J. Ecol. 102, 381-395.
- Lugliè, C., 2018. *Your path led trough the sea*... the emergence of Neolithic in Sardinia and Corsica.
   Quatern. Int. 470, 285-300.
- Ma, L., Vaquero, J.M., 2020. New evidence of the Suess/de Vries cycle existing in historical naked eye observations of sunspots. Open Astronomy 29, 28-31.

- Magny, M., Joannin, S., Galop, D., Vannière, B., Haas, J. N., Bassetti, M., Bellintani, P., Scandolari,
  R., Desmet, M., 2012. Holocene palaeohydrological changes in the northern Mediterranean
  borderlands as reflected by the lake-level record of Lake Ledro, northeastern Italy. Quaternary
  Res., 77, 382–396.
- Magny, M., Combourieu-Nebout, N., de Beaulieu, J.L., Bout-Roumazeilles, V., Colombaroli, D.,
  Desprat, S., Francke, A., Joannin, S., Ortu, E., Peyron, O., Revel, M., Sadori, L., Siani, G.,
  Sicre, M.A., Samartin, S., Simonneau, A., Tinner, W., Vannière, B., Wagner, B., Zanchetta,
  G., Anselmetti, F., Brugiapaglia, E., Chapron, E., Debret, M., Desmet, M., Didier, J.,
  Essallami, L., Galop, D., Gilli, A., Haas, J.N., Kallel, N., Millet, L., Stock, A., Turon, J.L.,
  Wirth, S., 2013. North-south palaeohydrological contrasts in the central Mediterranean during
  the Holocene: tentative synthesis and working hypotheses. Clim. Past 9, 2043-2071.
- Magri, D., Di Rita, F., 2015. Archaeopalynological preparation techniques, in: Yeung, E.C.T.,
   Stasolla, C., Sumner, M.J., Huang, B.Q. (Eds.), Plant Microtechniques and Protocols. Springer
   International Publishing, Cham, pp. 495–506.
- Magri, D., Celant, A., Di Rita, F., 2019. The vanished Alnus-dominated forests along the Tyrrhenian
   coast. Catena 182, 104136.
- 1011Martín-Chivelet, J., Muñoz-García, M.B., Edwards, R.L., Turrero, M.J., Ortega, A.I., 2011. Land1012surface temperature changes in Northern Iberia since 4000 yr BP, based on  $\delta^{13}$ C of1013speleothems. Global Planet. Change 77, 1-12.
- Martìn-Puertas, C., Matthes, K., Brauer, A., Muscheler, R., Hansen, F., Petrick, C., Aldahan, A.,
   Possnert, G., van Geel, B., 2012. Regional atmospheric circulation shifts induced by a grand
   solar minimum. Nat. Geosci. 5, 397-401.
- Mattioni, C., Martin, M. A., Pollegioni, P., Cherubini, M., Villani, F., 2013. Microsatellite markers
   reveal a strong geographical structure in European populations of *Castanea sativa* (Fagaceae):
   evidence for multiple glacial refugia. Am. J. Bot. 100, 951-961.
- Médail, F., Monnet, A.-C., Pavon, D., Nikoli<sup>´</sup>c, T., Dimopoulos, P., Bacchetta, G., Arroyo, J., Barina,
  Z., Albassatneh, M.C., Domina, G., Fady, B., Matevski, V., Mifsud, S., Leriche, A., 2019.
  What is a tree in the Mediterranean Basin hotspot? A critical analysis. Forest Ecosyst. 6, 17.
- Melis, R.T., Depalmas, A., Di Rita, F., Montis, F., Vacchi, M., 2017. Mid to late Holocene
  environmental changes along the coast of western Sardinia (Mediterranean Sea Global Planet.
  Change 155, 29-41.
- Melis, R.T., Di Rita, F., French, C., Marriner, N., Montis, F., Serreli, G., Sulas, F., Vacchi, M., 2018.
  8000 years of coastal changes on a western Mediterranean island: a multiproxy approach from the Posada plain of Sardinia. Mar. Geol. 403, 93-108.
- Michon, G., 2011. Revisiting the resilience of chestnut forests in Corsica: from social-ecological
   systems theory to political ecolog. Ecol. Soc. 16, 5.
- Moore, D.M., Reynolds, R.C. Jr., 1997. X-Ray diffraction and the identification and analysis of clay
   minerals. Oxford New York, Oxford Univ. Press, 378 pp.
- Pantaleón-Cano, J., Yll, E.I., Pérez-Obiol, R. Roure, J.M., 2003. Palynological evidence for
   vegetational history in semi-arid areas of the western Mediterranean (Almería, Spain). The
   Holocene 13, 109–19.
- Peche-Quilichini, K., 2011. Les monuments turriformes de l'Age du bronze en Corse: tentative de caractérisation spatiale et chronologique sur fond d'historiographie. In: Dominique Garcia (ed.) L'Age du bronze en Méditerranée. Recherches récentes, Errance, Paris, 155-170.
- Pedrotta, T., Gobet, E., Schwörer, C., Beffa, G., Butz, C., Henne, P.D., Morales-Molino, C., Pasta,
  S., van Leeuwen, J.F.N., Vogel, H., Zwimpfer, E., Anselmetti, F.S., Grosjean, M., Tinner, W.,
  2021. 8,000 years of climate, vegetation, fire and land-use dynamics in the thermomediterranean vegetation belt of northern Sardinia (Italy). Veget Hist Archaeobot. 30, 789813.
- Peyron, O., Combourieu-Nebout, N., Brayshaw, D., Goring, S., Andrieu-Ponel, V., Desprat, S.,
  Fletcher, W., Gambin, B., Ioakim, C., Joannin, S., Kotthoff, U., Kouli, K., Montade, V., Pross,

- 1046J., Sadori, L., Magny, M., 2017. Precipitation changes in the Mediterranean basin during the1047Holocene from terrestrial and marine pollen records: a model-data comparison. Clim. Past 13,1048249-265.
- Pichard, G., Arnaud-Fassetta, G., Moron, V., Roucaute, E., 2017. Hydro-climatology of the Lower
   Rhône Valley: historical flood reconstruction (AD 1300–2000) based on documentary and
   instrumental sources. Hydrolog. Sci. J. 62, 1772-1795.
- Poher, Y., Ponel, P., Médail, F., Andrieu-Ponel, V., Guiter, F., 2017. Holocene environmental history
   of a small Mediterranean island in response to sea-level changes, climate and human impact.
   Palaeogeogr. Palaeoecol. 465, 247-263.
- Pollegioni, P., Woeste, K., Chiocchini, F., Del Lungo, S., Ciolfi, M., Olimpieri, I., Tortolano, V.,
  Clark, J., Hemery, G.E., Mapelli, S., Malvolti, M.E., 2017. Rethinking the history of common
  walnut (*Juglans regia* L.) in Europe: its origins and human interactions. PLoS One 12,
  e0172541.
- 1059 Regattieri, E., Zanchetta, G., Drysdale, R.N., Isola, I., Hellstrom, J.C., Dallai, L., 2014. Lateglacial
  1060 to holocene trace element record (Ba, Mg, Sr) from corchia cave (Apuan Alps, central Italy):
  1061 paleoenvironmental implications. J. Quaternary Sci. 29, 381-392.
- Reille, M., 1975. Contribution pollen analytique à l'histoire tardiglaciaire et holocène de la végétation
   de la montagne corse. Thèse des sciences Aix-Marseille III.
- Reille, M., 1984. Origine de la végétation actuelle de la Corse sud-orientale; analyse pollinique de cinq marais côtiers. Pollen Spores 1 XXVI, 43-60.
- Reille, M., 1991. Les données de l'analyse pollinique. Rapport fouille programme Grotte du Norte di
   Tuda. Olmeta di Tuda, pp. 149-160.
- Reille, M., 1992a. New pollen-analytical researches in Corsica: the problem of Quercus ilex L. and
   Erica arborea L., the origin of Pinus halepensis Miller forests. New Phytol. 122, 359-378.
- 1070 Reille, M., 1992b. Pollen et spores d'Afrique du nord. Laboratoire de Bot. Hist. et Palynologie,
  1071 Marseille
- Reille, M.J., Gamisans, V., Andrieu-Ponel, V., De Balieu, J.-L., 1999. The Holocene at Lac de Creno,
   Corsica, France: a key site for the whole island. New Phytol. 141, 291-307.
- 1074 Reimer, P.J., Austin, W.E., Bard, E., Bayliss, A., Blackwell, P.G., Ramsey, C.B., Butzin, M., Cheng,
  1075 H., Edwards, R.L., Friedrich, M., Grootes, P.M., et al., 2020. The IntCal20 Northern
  1076 Hemisphere Radiocarbon Age Calibration Curve (0-55 cal kBP). Radiocarbon 62, 725-757.
- Revelles J., Ghilardi, M., Vacchi, M., Rossi, V., Currás, A., López-Bultò, O., Brkojewitsch, G., 2019.
   Coastal landscape evolution of Corsica: palaeoenvironments, vegetation history and human impacts since the Early Neolithic period. Quaternary Sci. Rev. 225, 105993.
- 1080 Revelles, J., Ghilardi, M., 2021. 49. Saint Florent (north Corsica, France). Grana 60, 158-160.
- Roberts, C. N., Woodbridge, J., Palmisano, A., Bevan, A., Fyfe, R., Shennan, S., 2019. Mediterranean
  landscape change during the Holocene: Synthesis, comparison and regional trends in
  population, land cover and climate. The Holocene, 29(5), 923-937.
- Rodwell, J.S. (ed.), 2000. British plant communities, vol. 5, Maritime communities and vegetation of
   open habitats. Cambridge: Cambridge University Press.
- Sabatier, P., Dezileau, L., Colin, C., Briqueu, L., Bouchette, F., Martinez, P., Siani, G., Raynal, O.,
   Von Grafenstein, U., 2012. 7000 years of paleostorm activity in the NW Mediterranean Sea
   in response to Holocene climate events. Quat. Res. 77, 1–11.
- Sabatier, P., Nicolle, M., Piot, C., Colin, C., Debret, M., Swingedouw, D., Perrette, Y., Bellingery,
  M.-C., Chazeau, B., Develle, A.-L., Leblanc, M., Skonieczny, C., Copard, Y., Reyss, J.-L.,
  Malet, E., Jouffroy-Bapicot, I., Kelner, M., Poulenard, J., Didier, J., Arnaud, F., Vannière, B.,
  2020. Past African dust inputs in the western Mediterranean area controlled by the complex
  interaction between the Intertropical Convergence Zone, the North Atlantic Oscillation, and
  total solar irradiance. Clim. Past 16, 283–298
- Schulz, M., Mudelsee, M., 2002. REDFIT: estimating red-noise spectra directly from unevenly
   spaced paleoclimatic time series. Computers & Geosciences 28, 421-426.

- Scott, L., 1992. Environmental implications and origin of microscopic *Pseudoschizaea* Thiergart and
   Frantz ex R Potonié emend. in sediments. J. Biogeogr. 19, 349-354.
- Szymczak, S., Joachimski, M. M., Bräuning, A., Hetzer, T., Kuhlemann, J., 2012. A 560 yr summer
   temperature reconstruction for the Western Mediterranean basin based on stable carbon
   isotopes from *Pinus nigra* ssp. *laricio* (Corsica/France). Clim. Past 8, 1737-1749.
- Sicurani, J., 2008. Étude technologique et typologique du matériel lithique taillé néolithique trouvé
  en place sur quelques sites majeurs du Nord-Ouest (Balagne) de la Corse. Thèse de Doctorat,
  Université de Corse, 714 p.
- Sicurani, J., Martinet, L., 2019. Teghja di Linu: un site de plein air du début du iiie millénaire av. J.C. (Luzzipeu, Haute-Corse). In Sicurani J. (dir.), L'habitat pré- et protohistorique/L'alloghju
  prestoricu è protostoricu, acte du Ier colloque de Calvi (Calvi, 28-30 avril 2017), ARPPC, 4570.
- Stax, R., Stein, R., 1993. Long-term changes in the accumulation of organic carbon in Neogene
   sediments, Ontong Java Plateau, Proc. Ocean Drill. Program Sci. Results 130, 573-584.
- Stos-Gale, Z., Gale, N.H., Houghton, J., Speakman, R., 1995. Lead isotope data from the Isotrace
   Laboratory, Oxford: Archaeometry data base 1, ores from the Western Mediterranean.
   Archaeometry 37, 407–415.
- Terral, J.-F., Alonso, N., Buxó i Capdevila, R., Chatti, N., Fabre, L., Fiorentino, G., Marinval, P.,
  Pérez Jordá, G., Pradat, B., Rovira, N., Alibert, P., 2004: Historical biogeography of olive
  domestication (Olea europaea L.) as revealed by geometrical morphometry applied to
  biological and archaeological material. J. Biogeogr. 31, 63–77.
- Trouet, V., Esper, J., Graham, N.E., Baker, A., Scourse, J. D., Frank, D.C., 2009. Persistent positive
  North Atlantic Oscillation mode dominated the medieval climate anomaly. Science
  324(5923), 78-80.
- Vacchi, M., Ghilardi, M., Spada, G., Currás, A., Robresco, S., 2017. New insights into the sea-level
  evolution in Corsica (NW Mediterranean) since the late Neolithic. J. Archaeol. Sci.: Reports,
  123 12, 782-793.
- Vacchi, M., Joyse, K. M., Kopp, R. E., Marriner, N., Kaniewski, D., Rovere, A., 2021. Climate pacing
   of millennial sea-level change variability in the central and western Mediterranean. Nature
   communications 12(1), 1-9.
- Vacchi, M., Marriner, N., Morhange, C., Spada, G., Fontana, A., Rovere, A., 2016. Multiproxy assessment of Holocene relative sea-level changes in the western Mediterranean:sea-level variability and improvements in the definition of the isostatic signal. Earth Sci. Rev. 155, 172-1130
  197.
- Vacchi, M., Ghilardi, M., Melis, R.T., Spada, G., Giaime, M., Marriner, N., Lorscheid, T., Morhange,
   C., Burjachs, F., Rovere, A., 2018. New relative sea-level insights into the isostatic history of
   the Western Mediterranean. Quat. Sci. Rev. 201, 396-408.
- van Geel, B., 2001. Non-pollen palynomorphs. In: Smol, J.P., Birks, H.J.B., Last, W.M. (Eds.),
   Tracking Environmental Change Using Lake Sediments. Terrestrial, Algal and Silicaceous
   Indicators, Volume 3. Kluwer, Dordrecht, pp. 99-119.
- 1137 Vecchio, A., Lepreti, F., Laurenza, M., Alberti, T., Carbone, V., 2017. Connection between solar
   activity cycles and grand minima generation. Astronomy & Astrophysics 599, A58.
- 1139 Vella, M. A., Tomas, É., Thury-Bouvet, G., Muller, S., 2014. Nouvelles données sur le petit âge de
  1140 glace en Corse: apports de l'analyse croisée des informations géomorphologique,
  1141 palynologique et archéologique de la piève de Santo Pietro (désert de l'Agriate, Corse).
  1142 Méditerranée. Revue géographique des pays méditerranéens/Journal of Mediterranean
  1143 geography, (122), 99-111.
- Vella, M.A., Andrieu-Ponel, V., Cesari, J., Leandri, F., Pêche-Quilichini, K., Reille, M., Poher, Y.,
  Demory, F., Delanghe, D., Ghilardi, M., Ottaviani-Spella, M.D., 2019. Early impact of
  agropastoral activities and climate on the littoral landscape of Corsica since mid-Holocene.
  PloS One, 14(12), e0226358.

- Vigne, J.D., 1984. Premières données sur les débuts de l'élevage du Mouton, de la Chèvre et du Porc
  dans le sud de la Corse (France), in: Clutton-Brock J. et Grigson C. (Eds.), Animals and
  Archaeology, 3 Early Herders and their Flocks. Proceedings 4th Int. Council for
  Archaeozoology, Londres, 1982, Oxford, Archaeopress, BAR International Series, 202, 4765.
- 1153 Vigne, J.D., 1987. L'exploitation des ressources alimentaires en Corse du VIIe au IVe millénaire. In
  1154 : Guilaine, J., Courtin, J., Roudil, J.L. et al. (Eds.), Premières communautés paysannes en
  1155 Méditerranée occidentale. CNRS éditions, 193-199.
- Weis, D., Kieffer, B., Maerschalk, C., Barling, J., de Jong, J., Williams, G.A., Hanano, D., Pretorius,
  W., Mattielli, N., Scoates, J.S., Goolaerts, A., Friedman, R.M., Mahoney, J.B., 2006. Highprecision isotopic characterization of USGS reference materials by TIMS and MC-ICP-MS.
  Geochem. Geophys. Geosyst. 7, Q08006.
- Weiss, M.-C., 2010. Au VIe millénaire avant notre ère. A Petra à L'île Rousse : campagnes de fouilles
   (2003-2006), Ajaccio, Albiana, 247 p.
- Wu, J., Yu, Z., Zeng, Z., Wang, N., 2009. Possible solar forcing of 400-year wet–dryclimate cycles
   in northwestern China. Climatic Change 96, 473-482.
- Yu, Z.C., Ito, E., 2002. The 400-year wet–dry climate cycle in Interior North America and its solar
   connection. In: West, G.J., Blomquist, N.L. (Eds.), Proceedings of the nineteenth annual
   pacific climate workshop. Technical Report 71, 159–163.
- Zanchetta, G., Regattieri, E., Isola, I., Drysdale, R., Bini, M., Baneschi, I., Hellstrom, J., 2016. The
   so-called "4.2 event" in the central Mediterranean and its climatic teleconnections. Alp.
   Mediterr. Quat. 29, 5-17.
- Zonneveld, K.A.F., Marret, F., Versteegh, G.J.M., Bonnet, S., Bouimetarhan, I., Crouch, E., de 1170 1171 Vernal, A., Elshanawany, R., Edwards, L., Esper, O., Forke, S., Grøsfjeld, K., Henry, M., 1172 Holzwarth, U., Kielt, J.-F., Kim, S.-Y., Ladouceur, S., Ledu, D., Chen, L., Limoges, A., Londeix, L., Lu, S.-H., Mahmoud, M.S., Marino, G., Matsouka, K., Matthiessen, J., 1173 1174 Mildenhal, D.C., Mudie, P., Neil, H.L., Pospelova, V., Qi, Y., Radi, T., Richerol, T., Rochon, 1175 A., Sangiorgi, F., Solignac, S., Turon, J.-L., Verleye, T., Wang, Y., Wang, Z., Young, M., 1176 2013. Atlas of modern dinoflagellate cyst distribution based on 2405 datapoints. Rev. Palaeobot. Palynol. 191, 1-197. 1177
- 1178 1179

LablID	Material	Depth (cm)	<sup>14</sup> C Age±error BP	Cal. yr BP (2σ)	Cal. yr AD/BC (2σ)
GdA-5806	Organic sediment	49	1585±25	1527-1404	423-546 AD
Poz-115796	Organic sediment	50	3090±40	3389-3179	1440-1230 BC
GdA-5807	Organic sediment	77	2215±30	2330-2146	381-197 BC
GdA-5808	Organic sediment	93	2280±25	2349-2177	400-209 BC
Poz-110261	Charcoal	125	3260±90	3699-3252	1750-1301 BC
GdA-5809	Organic sediment	138	3090±35	3382-3210	1433-1261 BC
GdA-5810	Organic sediment	154	3215±30	3480-3373	1531-1424 BC
Poz-110260	Plant + Peat	185	3420±35	3823-3569	1874-1620 BC
GdA-5811	Organic sediment	229	4170±40	4834-4577	2885-2628 BC
Poz-110258	Peat	270	4175±35	4835-4580	2886-2631 BC
Poz-109794	Charcoal	340	4470±40	5297-4967	3348-3018 BC
Poz-110198	Peat	397	4530±30	5312-5051	3363-3102 BC
Poz-109887	Charcoal	450	4730±40	5581-5325	3632-3376 BC
Poz-105992	Bulk Sediment	487	5080±40	5917-5730	3968-3781 BC

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1181 Table 1. AMS Radiocarbon ages obtained from the materials of Crovani core. The calibrated ages

1182 are based on Intcal20 dataset (Reimer et al., 2020).

### 1184 Figure Captions

- 1185 Figure 1. Location map of the study area and coastal sites of previous palynological research (white
- 1186 circle) conducted over the last decade for Corsica island (Del Sale: Currás et al., 2017; Sagone:
- 1187 Ghilardi et al., 2017a; Palo, Piantarella and Saint-Florent: Revelles et al., 2019, Revelles and
- 1188 Ghilardi, 2021; Canniccia: Vella et al., 2019). The purple squares indicate the position of known
- 1189 mining sites of galena/lead in Corsica. A: Hydrography and archaeology of the catchment basins
- ending in the Crovani Bay, green circle: Final Neolithic to Bronze Age site; Red circle: possible
- roman site of occupation; Orange square: 19th to 20th Cent. AD mining buildings; light green stars:
- 1192 Medieval site; 1: San Larenzu, 2: San Quilicu, 3: Teghja di Linu, 4: lower Argentella, 5: upper
- Argentella. B: Simpilified geology and topography of the catchment basins ending in the Crovani
  Bay; Orange square: mining site Geographic coordinates are expressed in WGS 84 geodetic system.
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- Figure 2. View of the Crovani pond, borehole and Differential Global Positioning System- DGPSprofile (AA') locations. The light blue line (dash) indicates the present-day course of the rivers.
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Figure 3. Age-Depth Model of the Crovani sequence, calculated through a Bayesian method using
the computer program Bacon 2.5.5 (Blaauw and Christen, 2011). The Model is based on 14 AMS
dates calibrated using the IntCal20 curve (Reimer et al., 2020).

Figure 4. Core lithology with ages expressed in cal. BC/AD and depths indicated in cm (left). For full details of the samples performed for 14C AMS dating method (red squares), please check Table 1. Curves from left to right: Loss on ignition measurements with organic matter and carbonate contents, granulometric indexes (mean and mode), mineralogical and geochemical proxies (halite, C/N ratio) and Arboreal Pollen (AP) concentration (grains/gram).

1209 Figure 5. A: Pb isotope results of the Crovani sedimentary core LCr18 reported in a binary diagram <sup>207</sup>Pb/<sup>206</sup>Pb versus <sup>208</sup>Pb/<sup>206</sup>Pb. The dashed line indicates the linear regression trend between the 1210 1211 Crovani samples. Circles: Crovani samples reported by different colors according to their 1212 stratigraphical position, i.e. pre-Roman samples, Roman and modern samples. The black circle 1213 indicates the average signature of the local geological background defined by the oldest measured 1214 Chalcolithic Final Neolithic samples. Black symbols: samples from different Pb-bearing mineral 1215 collected in West Corsica. The red triangle gives the averaged composition of modern airborne 1216 [FN1] particles collected above Roma in Italy (data from Bollhöfer and Rosman, 2001). Green squares: 1217 signature of Pb galene-rich ores from Sardinia. B: Close up emphasizing the representative signature 1218 of Pb ore mining districts surrounding the Mediterranean basin classed by country (green for Italy, 1219 blue for Greece, purple for Turkey and various colors from grey to orange for Spain ores). Data from 1220 literature reported in Fagel et al., (2017). The black arrow represents an extrapolation of the sedimentary mixing observed in core LCr18 in Figure 5A. It underlines the probable implication of 1221 1222 the minerals of Tuscany in the Pb isotope signature of the Crovani sediments.

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- Figure 6. Pollen percentage diagram of Crovani, including the pollen zonation calculated with the
  CONISS method (Grimm, 1987).
- 1227 Figure 7. Percentage diagram of Non-Pollen Palynomorphs from Crovani.

Figure 8. Summary pollen diagram including the cumulative percentages of gymnosperms, riparian trees, deciduous trees, evergreen trees and shrubs, OJCV curve, anthropogenic herbs, other herbs, coprophilous fungi, and saproxylic and phytopathogenic fungi), the Arboreal Pollen percentage record, the concentrations of Arboreal Pollen and Non-Arboreal Pollen, and the microcharcoal concentrations. The light green bars indicate phases of high storm activity in southern France (Sabatier et al., 2012). The blue bars indicate lake level highstands at Lake Accesa in central Italy
(Magny et al., 2013). The orange bars indicate phases of dry climate conditions in south-central
Mediterranean (Di Rita et al., 2018a). The NAO index is based on Franke et al. (2017).

Figure 9. REDFIT (A) analysis of the total Arboreal Pollen percentages (B) using the PAST 3.2 software program (Hammer et al., 2001). In the REDFIT spectral analysis the time series is fitted to an AR1 red noise model (orange line). The 95% confidence levels of the  $\chi^2$  and Monte Carlo tests are reported on the graph with a green dashed line and a red dashed line, respectively.

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Figure 10. Synoptic table with timing and nature of key environmental changes reconstructed fromthe Crovani record.

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# Highlights

- A new palynological, sedimentological and geochemical study is presented from a coastal wetland of Corsica.
- The high-resolution 6000-year pollen record shows an unprecedented long persistence of *Erica* and *Quercus ilex* maquis.
- Human activities developed especially during the Late and Final Neolithic and the last 1000 years.
- Evidence of agriculture predates any Neolithic archaeological findings in this region.
- The 4.2 ka event, Homeric Minimum, and Little Ice Age are not associated with forest declines.

1	Natural and anthropogenic dynamics of the coastal environment in
2	northwestern Corsica (Western Mediterranean) over the past six millennia
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4	Federico Di Rita <sup>1*</sup> , Matthieu Ghilardi <sup>2</sup> , Nathalie Fagel <sup>3</sup> , Matteo Vacchi <sup>4</sup> , François Warichet <sup>3</sup> ,
5	Doriane Delanghe <sup>2</sup> , Jean Sicurani <sup>5</sup> , Lauriane Martinet <sup>6</sup> , Sébastien Robresco <sup>7</sup>
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- 24 Abstract
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The present paper provides new insights into the climatic and anthropic factors that influenced a 26 27 6000-year coastal evolution in northwestern Corsica, the third largest island of the western 28 Mediterranean. Pollen, microcharcoal, sedimentary and geochemical analyses were carried out 29 on a core drilled in the Crovani coastal wetland to reconstruct the regional drivers of landscape 30 change. We show that anthropogenic and climate-induced fires favoured the development of 31 Mediterranean maquis, dominated by Erica and Quercus ilex, from ca. 6000 to 3350 cal. BP. A 32 change in arboreal vegetation triggered a short but intense sediment input in the Crovani pond between ca. 3350 and 3200 cal. BP. This is consistent with a coeval process of runoff recorded in 33 34 several coastal sites of western Corsica and related to an arid climate change occurred in many 35 sites of the western Mediterranean around 3200 years ago. We provide evidence of agriculture during the Late Neolithic from ca. 3900 BC, which is much earlier than any archaeological 36 37 evidence previously available in this area of Corsica, followed by a progressive decline of arable 38 farming practices. Human impact has been responsible for a degradation of the maquis only from 39 approximately 3000 cal. BP, and it intensified in Roman times, when the area experienced the 40 first phase of galena exploitation from the Argentella mines. Over the last 500 years, the present 41 work evidences a major development of Castanea related to cultivation during the Genoese 42 administration of Corsica. Our findings suggest that solar activity and the North Atlantic 43 Oscillation had an influence on centennial-scale forest cover variations during the last 6000 years.

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Keywords: Corsica, pollen, palaeoenvironments, isotope geochemistry, geoarchaeology, western
 Mediterranean, Holocene

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#### 1. Introduction

49 The island of Corsica hosts the largest number of coastal wetlands among the Mediterranean islands 50 (Ghilardi, 2020 and 2021). Most of them formed after the Mid-Holocene sea-level stabilization that 51 occurred in the Mediterranean Basin between 7000 and 6000 cal. BP (Vacchi et al., 2016, 2018). 52 Amongst the ~200 coastal wetlands of the island, brackish lagoons and coastal ponds are the most 53 common geomorphological features (Ghilardi, 2020).

The remarkable potential of pollen analysis to trace the main changes in the costal landscape of the island was first highlighted by the excellent palynological work of Maurice Reille (Reille, 1984, 1991,1992a). However, these pollen data were not provided with a robust chronology and did not include the analysis of Non-Pollen Palynomorphs (NPPs) and other palaeonvironmental proxies from the same core. In the last few years, several Corsican wetlands situated at a short distance of the sea were the subject
 of multiproxy geoarchaeological research on the environmental impact of human activities, especially

61 in Prehistoric and Protohistoric times (Early Neolithic to Final Bronze Age, ca. 7500 BP to 2800 BP)

62 (Currás et al., 2017; Ghilardi et al., 2017a; Revelles et al., 2019; Vella et al., 2019; Figure 1). The

63 study of different palaeoecological proxies, such as ostracods, molluscs, and pollen, combined with 64 the chronostratigraphy of sediments, has shown the interest of reconstructing both the paleogeography 65 and the history of the vegetation of coastal Corsica starting from the ancient Neolithic (Cardial 66 culture, starting from 7500  $\pm$  200 cal. BP; D'Anna et al., 2001; Lugliè, 2018).

- The information of palaeoenvironmental records from Corsica is paramount for detailed reconstructions of both land-use patterns and centennial-scale climate changes in the Mediterranean Basin. Indeed, the island was a crossroad for many European and North African populations in the conquest of the Mediterranean and occupies a strategic geographical location, potentially sensitive to both North Atlantic climate patterns and north African atmospheric drivers (Sabatier et al., 2020).
- The aim of this paper is to outline the landscape evolution in northwestern coastal Corsica over the last six millennia, taking advantage of the recent progress in palaeoenvironmental reconstructions (Henry ed., 2020), chronological models (Reimer at al., 2020), and new insights into the centennialscale patterns of atmospheric circulation during the Middle and Late Holocene (Franke et al., 2017; Di Rita et al., 2018a; Sabatier et al., 2020).
- 77 Our new palynological and stratigraphical data are addressed to contribute to prominent unsolved 78 questions about times and drivers of vegetational change in Corsica, with a special focus on the 79 replacement of *Erica* shrublands with *Quercus ilex* woody formations during the Middle Holocene. 80 A second key topic is the origin and development of land use practices in northwestern Corsica. In 81 Neolithic times, there is sparse archaeological evidence for cereal cultivation and pastoral activities 82 along the coasts of Corsica. Cereal cultivation was revealed by pollen analyses only in the eastern 83 plain of Corsica and in the Saint Florent and Bonifacio-Piantarella areas (Currás et al., 2017; Revelles 84 et al., 2019), while the osteological identification of mammals buried in sheltered caves from southern 85 and northern Corsica provided evidence about the development of stockbreeding (Vigne, 1984, 1987). 86 A third unsolved question is related to the controversial role of climate changes in modifying the 87 vegetational landscape of Corsica. While at millennial time scale the influence of climate changes on 88 the vegetation and fires of the island has been clearly recognized (Reille 1992a; Leys et al., 2013; 89 Revelles et al., 2019; Lestienne et al., 2020a, b), the role of rapid climate changes (RCC) has been 90 seldom evoked in the regional palaeobotanical narrative. The apparent lack of vegetation responses 91 to centennial climate changes was attributed to either the overshadowing effect produced by local 92 resilient shrublands (Revelles et al., 2019) or the geographical position of Corsica, located in a

93 possible climate-unsensitive transitional area between the central and western Mediterranean (Di Rita

and Magri, 2019; Di Rita et al., 2022), two regions where RCC often produced contrasting moisture

95 changes (Di Rita et al., 2018a).

New detailed palaeoenvironmental data from Corsica are thus needed to disentangle these questions,
which are relevant for a better understanding of the natural and anthropogenic landscape changes in
the Mediterranean during the Holocene.

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#### 100 **2.** Study area

101 2.1. Present day landscape and vegetation

The Crovani pond is located in NW Corsica, in the westernmost part of a ~1 km<sup>2</sup> coastal plain (Fig.
1A). The plain collects the waters from two catchment basins with intermittent flow: the ArgentellaCardiccia streams (catchment basin ~6 km<sup>2</sup>), incising metamorphic rocks (shales and micaschists)
and syenogranite, and the Marconcellu-Fiuminale streams (total catchment area: ca. 23 km<sup>2</sup>), draining
granodiorites, syenogranite, and Pliocene to Pleistocene screes in the lowermost river course (Fig.
1B).

108 Corsica has a typical Mediterranean climate highly influenced by its relief topography. The mean 109 annual temperature on the whole Island ranges between  $14.5^{\circ}$ C and  $16.5^{\circ}$ C and the mean annual 110 precipitation is 890 mm per year. On the coastal area, mean annual temperature is higher (17°C) and 111 freezing temperatures during the year are very seldom reported (Vella et al., 2019).

The Crovani wetland covers an area of  $\sim 0.3 \text{ km}^2$  behind a thick coastal barrier  $\leq 5.30 \text{ m}$  above the mean sea level (amsl), made up of large well-rounded pebbles and cobbles (Fig. 2). The pond, which is at 0.75 m amsl in the winter, is seasonal dry in the summer and has no direct link to the sea.

115 The surrounding wetland is a protected area, being included in the ZNIEFF (Zone naturelle d'intérêt

116 *écologique, faunistique et floristique*) n. 940004139 '*Etang et zones humide de Crovani*' with the aim

117 of preserving the following angiosperm species: *Euphorbia peplis* L., *Polygonum scoparium* Req. ex

118 Loisel., Ranunculus ophioglossifolius Vill., Staphisagria picta (Willd.) Jabbour, Tamarix africana

119 Poir., and Vitex agnus-castus L. The pond is surrounded by a belt of T. africana and is characterized

120 by a wet meadow covered by palustrine species dominated by *Bolboschoenus maritimus* (L.) Palla,

121 Juncus acutus L. and Juncus maritimus Lam. The coastal bar is occupied by a population of Pistacia

122 *lentiscus* L. and, on the top of the beach, by one of the most important Corsican populations of *Vitex* 

123 agnus-castus (https://inpn.mnhn.fr/zone/znieff/940004139). In spring, the very rare S. picta grows

among the pebbles (Jeanmonod and Schlüssel, 2006). The woody vegetation of the site consists of a

125 degraded maquis with Erica arborea L., Arbutus unedo L., Pistacia lentiscus L., Phillyrea

126 *angustifolia* L. and sparse *Quercus ilex* L. (Reille, 1992a).

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# 128 2.2. Local archaeology and history of the human occupation

129 The first evidence of human settlement in Corsica dates back to the Mesolithic (Lugliè, 2018). 130 Abundant archaeological material allows to reconstruct the Neolithic settling history of the island 131 (Lugliè, 2018; Revelles et al., 2019). In northern Corsica a rich archaeological background is found 132 in a Mesolithic to Early Neolithic occupation in the Nebbiu area, at the Saint-Florent/Patrimonio sites 133 (Revelles et al., 2019). In the Balagne area, an important human occupation in a coastal context is 134 attested by the Early Neolithic site (Cardial culture) of La Petra, situated on a peninsula north of the modern town of L'Île Rousse (Weiss, 2010). 135 136 In the Luzzipeu sector, situated in the southern part of the Balagne micro region, where the Crovani

pond is located (Fig. 1A), despite the paucity of recognized prehistoric settlements and uncovered 137 archaeological material, there is evidence of occupation during the Final Neolithic (starting from ca. 138 139 2800 cal. BC) at Teghja di Linu (Fig. 1A). The last site consists in a small village composed of huts, 140 located at an elevation of ~40 m amsl at ~1.5 km distance from the Crovani pond, where lithics were 141 discovered together with a menhir statue (Sicurani, 2008; Sicurani and Martinet, 2019; Ghilardi, 142 2020). Possible evidence of occupation during Late Neolithic times was hypothesized, but the lithics 143 uncovered are still under investigation (Sicurani and Martinet, 2019). Due to the presence of acidic 144 soils, derived from the erosion of the granitic bedrock, preservation of biological remains and 145 archaeological material in this stratigraphical context is difficult, so that there is no organic material 146 left in the archaeological layers that may help to evaluate the type of activities developed at the Teghja 147 di Linu site. Excavations conducted over the last two decades have revealed the existence of a habitat 148 composed of several circular large structures, delimited by tremendous rounded granitic boulders.

149 Protohistoric settlements are hardly documented in the Luzzipeu lowlands. Bronze Age sites are 150 situated more inland, generally on top of hills (Peche-Quilichini, 2011). Iron Age and Roman times 151 are poorly documented, but archaeological surveys have revealed the presence of tegulae within the mining complex of the Argentella, in use in the 19<sup>th</sup> to 20<sup>th</sup> century CE, indicating a first phase of 152 153 galena exploitation (Leleu, 2021). This sparse human occupation from Bronze Age to Roman times radically contrasts with the Medieval archaeological remains attested at San Larenzu and San Quilicu 154 (Fig. 1A). Both are Romanic churches dated from the 11<sup>th</sup> Century CE and nowadays almost 155 disappeared due to their gradual destruction. From the Genovese administration to the French 156 administration, the region was attractive for the exploitation of natural resources, especially galena 157 minerals. Evidence for mining from the 16<sup>th</sup> to the early 20<sup>th</sup> centuries has been recorded (Leleu, 158 2021) but its impact in terms of landscape changes has never been investigated. 159

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#### 161 **3. Materials and Methods**

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In this paragraph we present a synthetic version of materials analysed and techniques we used. For a more exhaustive explanation of the methodology applied in this research we refer to information reported in the Supplementary data.

- 166The analyses presented in this study were carried out on a 6.25 m long sediment sequence, which was167collected with a 50-mm vibracore (COBRA TT equipment Atlas Copco) in the central part of the
- 168 Crovani pond in August 2018 (Fig. 2).
- The chronostratigraphy of the core was established using a series of 14 AMS radiocarbon determinations made in the Poznan and Gliwice (Poland) Radiocarbon Dating Laboratories. The Bayesian age-depth model (Fig. 3) was constructed using the software Bacon version 2.5.5 (Blaauw

and Christen, 2011) with dates calibrated using the IntCal20 curve (Reimer et al., 2020).

- Loss-on-ignition (LOI) measurements were performed on sediment samples of approximately 1 g
  taken at 10 cm intervals throughout the sequence, following the standard procedures published in
  Dean (1974) and Bengtsson and Enell (1986). (Fig. 4).
- Samples used for LOI measurements were also analysed for granulometry. The grain-size distribution
  of the fine fraction (<2 mm) was measured by laser diffraction granulometry at CEREGE.</li>
- A *C/N* analysis was carried out on 28 samples from the core, selected according to their organic matter content: a minimum of 5% by weight of organic matter was required to continue. The method by Stax and Stein (1993) was used as a basis for the preparation of the samples. Results were obtained using an elementary analyser (Vario Microcube, Elementar) coupled to a mass spectrometer (Isoprime
- 182 1000) (Fig. 4).
- The bulk mineralogy was measured on 28 samples in the upper 261 cm of the core. Most of the samples were retrieved from clayey sediments between 116 and 261 cm (20 samples), with a sampling resolution of 4 cm. In addition, 8 samples were retrieved between 11 and 106 cm. About 1 gram of dried bulk sediment sample was hand ground for mineralogical analyses. X ray diffraction (XRD) patterns of non-oriented powders (Moore and Reynolds 1997) were acquired between 2 and 30° 20 angle by using a Bruker D8-Advance Eco 1 Kw diffractometer equipped with a ceramic copper (Ka radiance with  $\lambda = 1.5418$  Å). The XRD data measured under a current intensity of 25 mA and a
- 190 voltage of 40 KV were recorded with a Lynxeye Xe energy dispersive detector in the laboratory
- 191 AGEs at the University of Liège. The minerals were identified by their peak positions and their
- abundance was calculated from the intensity on selected diffraction peaks (Cook et al. 1975).
- 193 The bulk samples for Pb isotopes analyses were digested using a tri-acid attack of HF/HNO<sub>3</sub>/HCl in
- a laminar flow hood. The Pb purification was made according to the procedures published in Weis et

- al. (2006). The Pb isotopes were measured by static multicollection in dry mode on a Nu Plasma I MC-ICP-MS instrument at the University of Brussels. The values were normalized using the recommended NBS981 values ( $^{208}$ Pb/ $^{204}$ Pb 36.7219 ± 61,  $^{207}$ Pb/ $^{204}$ Pb 15.4963 ±17,  $^{206}$ Pb/ $^{204}$ Pb 16.9405 ± 24) from Galer and Abouchami (1998). The Pb isotopes ratios were measured on 24 clayey samples retrieved in unit VI and VIII with a ~5 cm sampling resolution between 11 and 260 cm (Table
- 200 **S**1).
- In addition, some Pb-bearing minerals were collected in different Corsican ores or mineralised veins
  on the Paleozoic granites from west Corsica (Fig. 5). We have sampled the main Pb mineral galena
  (PbS) and also some Pb-bearing minerals like arsenopyrite (FeAsS). Galena was sampled in the mine
  of Argentella, 2.5 km from the Crovani pond but also in the mine of Lozari (along the northwestern
  coast, east of Île Rousse) and in a mineralized vein in Prunelli (south of Porto see locations in Fig.
  In addition, an arsenopyrite mineral sample was collected in the Finosa Pb-Zn-Ag ore close to
- 207 Ghisoni (Fig. 1).

Pollen analysis was carried out on 62 samples. Pollen extraction followed the standard procedures
 summarized by Magri and Di Rita (2015). Pollen grains and NPPs were identified by light microscope

- at 400 and 640 magnifications, with the help of both pollen morphology atlases (e.g., Reille, 1992b;
- Beug, 2004) and NPPs reference articles (e.g., Van Geel, 2001; Cugny et al., 2010; Gelorini et al.,
- 2122011).
- Microcharcoal analysis was carried out to reconstruct fire history, following the procedures described by Clark (1982). A series of 150 microscope fields were checked for each sample. Microcharcoals smaller than 5 µm were excluded from the sum. The computer program Psimpoll 4.27 (Bennett, 2009) was used to plot the percentage and concentration diagrams, as well as to subdivide the pollen record into 8 local assemblage zones, numbered from the base upwards and prefixed by the site abbreviation CRO, by means of the CONISS method (Grimm, 1987).
- A REDFIT spectral analysis (Schulz and Mudelsee, 2002) using the PAST 3.2 software (Hammer et al., 2001) was applied to the unevenly spaced time series represented by the total Arboreal Pollen (AP) percentages to detect the possible occurrence of a fundamental tempo in the forest cover changes.
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## 224 **4. Results**

225 *4.1.Chronostratigraphy* 

Based on the laser grain size determination and on the organic matter/carbonate contents, eight
stratigraphic units were defined from the bottom to the top (Fig. 4).

Unit I is found between 6.25 and 5.95 m depth. It consists of a mixture of well-rounded pebbles cemented within a sandy matrix and grey clays containing from 2 to 5% of organic matter. Due to the paucity of organic material, radiocarbon dating of this sedimentary unit was impossible.

Unit II is found between 5.95 and 5.45 m depth. It comprises medium to coarse grey sands with local

intercalations of angular gravels (centimetric in size). Organic matter and carbonate content are very

low (1-2%), hindering any radiocarbon dating of Unit II. No biomarkers were identified.

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Unit III is encountered between 5.45 and 3.73 m depth (~6300-5170 cal. BP; ~4350-3220 BC). It consists of homogeneous grey clays. The organic matter content ranges between 10 and 15% while carbonate content shows values comprised between 6 and 9%.

Unit IV occurs from 3.73 to 2.95 m depth (5170-4760 cal. BP; 3220-2810 BC). It shows features
similar to Unit II. It consists of coarse sands with intercalated layers of gravels with sharp edges,

239 witnessing variations in the energy of deposition, in particular at the point of changeover with Unit

240 III. In the lowermost part of Unit IV, a layer of 15 cm consists of angular gravels without sedimentary

241 matrix. Organic matter and carbonate contents (both < 2%) are low, like Unit II. Radiocarbon dating

of this lowermost portion is consistent with a time interval encompassing the Late to Final Neolithic.

Unit V, between 2.95 and 2.72 m depth (4760-4630 cal. BP; 2810-2680 BC), consists of organic
coarse sandy clays. Organic matter content increases upwards (1-7%). The carbonates content is
lower than 2%.

Unit VI is found from 2.72 and 1.42 m depth (4630-3320 cal. BP; 2680-1370 BC) and exhibits sedimentological parameters similar to Unit V. It consists of organic clays with 10-20% of organic matter and  $\leq 8\%$  of carbonate. The XRD mineralogy (Fig. S1) reveals the dominance of detrital minerals (~50% of quartz, K-feldspars and plagioclase with traces of amphibole and chlorite). They are associated to clayey minerals (~30% of total undifferentiated clays), aragonite (3 to 8%) from biogenic fragments and evaporites (8% < halite < 12% - Fig. 4). Radiocarbon dating of the unit is consistent with a time interval ranging from Final Neolithic to Middle Bronze Age.

Unit VII is encountered from 1.42 to 1.32 m deep (3320-3190 BP; 1370-1240 BC). It consists in a thin layer (10 cm) of homogeneous yellow fine sands showing a modal index of 90  $\mu$ m with a mean grain size of 20  $\mu$ m (fine silts). The granulometric analyses exhibit a multimodal distribution of the particles. Positive excursion in detrital minerals (cumulated abundance over 70 %). is observed for Unit VII and corresponds to a significant increase in quartz (28%) and plagioclase (25 %) and a relative drop in total clays minerals (13%) (Fig. S1).

Sedimentary Unit VIII is identified in the uppermost 1.32 m depth (3190-0 cal. BP; 1240 BC-1950
AD). Homogeneous grey clays record numerous traces of oxidation corresponding to rootlets. The
organic matter content is homogeneous (6 to 8%), while carbonate content is low (2-3%). The XRD

mineral association remains similar to unit VI, except the abundance of evaporites. A drop of halite
below 4% occurs between 166 and 150 cm, i.e. in the upper part of unit VII but close to the transition
with unit VI (Fig. 4). The rate of sediment accumulation for Unit VIII is very low, with values of ~4.3
mm per century.

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The uppermost 2 m sediment, spanning the last four millennia, were investigated for C/N ratio (Fig. 4). The averaged C/N ratio is high (> 10) and exceeds a value of 16 above 1.16 m suggesting a mainly terrestrial origin of the organic matter. The values range between 11 to 14 from 1.16 to 2 m, indicating a mixture of organic matter from vascular plants and algae. The highest value (~30) measured at 1.36 m indicates an episode of high input of sediments of continental origin, with a mix of vascular plants and cellulosic plants, dated ca. 1430 to 1260 BC.

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## 4.3. Lead isotopes analyses

The three Pb isotopic ratios evolve in parallel in the 260-upper cm, from Final Neolithic to present (Fig. S2). The  ${}^{208}$ Pb/ ${}^{204}$ Pb ranges between 38.60 and 39.01 (average 38.9353 ±0.0019), the  ${}^{207}$ Pb/ ${}^{204}$ Pb between 15.65 and 15.68 (average 15.6703 ±0.0007), and the  ${}^{206}$ Pb/ ${}^{204}$ Pb between 18.61 and 19.11 (average 19.02 ±0.0008) (Table S1). Even if some scattering of the data is observed for the studied pre-Roman period (i.e., 260-93 cm), the isotopic Pb ratios depict a marked decreasing trend upwards. This major change starts at 73 cm (Fig. S2) during the Roman period and continues over the modern period. The lowest isotopic ratios are measured in the shallowest samples at 11 and 17 cm.

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# 285 *4.4.Pollen analysis and statistical analysis on pollen time series*

The results of pollen analysis are presented as: 1) a detailed percentage diagram, including most of the pollen taxa and a summary Arboreal Pollen (AP)/Non Arboreal Pollen (NAP) percentage diagram, plotted against age (Fig. 6); 2) a percentage diagram displaying the main NPPs (Fig. 7); 3) a synthetic diagram including cumulative pollen percentages of ecological groups (conifers, riparian trees, deciduous trees, evergreen trees and shrubs, OJCV (*Olea+Juglans+Castanea+Vitis*), anthropogenic herbs, other herbs, coprophilous fungi, and saproxylic and phytopathogenic fungi), AP percentage, the concentrations of AP and NAP, microcharcoals, and some climate proxies (Fig. 8).

293 The pollen preservation was good with percentages of undeterminable grains seldom exceeding 4%.

An average of 310 pollen grains of terrestrial taxa per sample were counted. The biodiversity was represented by 92 different pollen taxa (terrestrial + aquatic plants) summed to 45 types of ferns, algae, fungi, and other NPPs. The palynological richness, estimated by rarefaction analysis (Birks and Line, 1992), is always over 15 terrestrial pollen types per sample. Total pollen concentrations vary from 7000 to 321,000 terrestrial pollen grains/g sediment. The features of the local pollen assemblage zones are summarized in the Supplementary Materials.

A REDFIT analysis was applied to the unevenly sampled time series represented by the total AP percentages, which show a clear fluctuating trend consistent with changes in forest cover rather than random fluctuations due to pollen representation and preservation (Fig. 9).

The results of the REDFIT exhibit a peak in power spectrum exceeding 95% of the false-alarm levels of both  $\chi^2$  and Monte Carlo tests, corresponding to a statistically significant periodicity of ca. 228 years (time=1/frequency), and less significant frequencies centred at 996 and 430 years, which however exceed 90% of the false-alarm levels of both  $\chi^2$  and Monte Carlo tests (Fig. 9).

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### 308 **5. Discussion**

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## 310 5.1. Evolution of the vegetational landscape

During the Middle and Late Holocene, from ca. 6100 to 1000 cal. BP (4150 BC-950 AD), the Crovani 311 312 pond was surrounded by a dense Erica-dominated tall maquis, accompanied by several evergreen 313 elements, such as *Q. ilex*, *Phillyrea*, *Pistacia*, and *Olea* (Figs 6, 8, and 10). This observation is 314 consistent with other palynological studies from southern Corsica (Reille, 1975, 1984; Revelles et al., 315 2019, Vella et al., 2019) and on the Cavallo island, situated in the strait of Bonifacio (Poher et al., 316 2017). An almost continuous record of Arbutus indicates that strawberry trees was a common 317 presence in the Erica arborea formations, as its pollen tetrads are poorly dispersed. The most 318 degraded sectors of this *maquis* vegetation were probably occupied by law shrublands of *Cistus*, 319 which played a prominent role in the dune and sandy soil vegetation together with Olea, Pistacia and 320 other thermophilous shrubs, as also reported from other coastal sites of western Corsica (Reille, 321 1992a).

The pollen record from Crovani provides new data to investigate the complex interplay between *Erica*-dominated and *Q. ilex*-dominated vegetation and their turnover in Corsica. According to Reille (1992a), *Erica* woodlands, representing the climax vegetation in lowland areas of western Corsica, underwent a major degradation process since the neolithization of the island, as a result of increasing human impact. It was largely replaced by *Quercus ilex* during the Mid- to Late Holocene (Reille, 1992a, Carcaillet et al., 1997). Recent palynological studies (Revelles et al., 2019) confirmed the

328 anthropic causation of this vegetation turnover and suggested that it started with the development of 329 agropastoral practices during the Early Neolithic, hence significantly earlier than the period 330 previously identified by Reille (1992a). Similar vegetation dynamics were reported also in Sardinia, 331 where a clear development of *Quercus ilex*, leading to a partial or complete replacement of the late successional *Erica* shrublands, is recorded since the 6<sup>th</sup> millennium BP (Di Rita and Melis, 2013; 332 333 Beffa et al., 2016; Melis et al., 2017, 2018; Pedrotta et al., 2021). In contrast, the pollen record from 334 Crovani (Fig. 6) indicates that the frequencies of Erica were continuously high until ~2900 BP and were not replaced by Q. ilex. Our pollen record even shows two temporary major increases in Erica 335 336 at the expense of holm oaks in the time-intervals 4700-4300 and 3350-2900 cal. BP. High frequencies 337 and concentrations of *Erica* and *Q. ilex* concur in depicting a *maquis* characterized by high biomass 338 and decomposed organic matter, as suggested by generally high values in the loss of ignition and a 339 significant presence of saproxylic and phytopathogenic fungi, such as Kretzschmaria deusta, 340 Asterosporium and Xylariaceae (Fig. 7)..

341 In Sardinia, Beffa et al. (2016) hypothesise that a protracted dominance of Erica and the absence of 342 evergreen oak forests in the first part of the Middle Holocene (until ca. 5300 cal. BP) were related to 343 warmer/drier summers and cooler/moister winters than today. They suggest that also in Corsica such 344 a climate regime, characterized by frequent and prolonged droughts during the spring and summer, 345 may have led to frequent seasonal wildfires advantaging communities dominated by Erica scoparia 346 and Erica arborea, which are two fire-adapted species able to quickly resprout and generate new 347 aboveground biomass after frequent and intense fires. In contrast, *Quercus ilex* is considered to have 348 been severely affected by natural and anthropogenic fires and favoured by a climate change leading 349 to increased summer rainfall and decreased fire occurred at the end of the Middle Holocene 350 (Colombaroli et al., 2009; Beffa et al., 2016; Pedrotta et al., 2021).

351 In contrast to this view, at Crovani, high concentrations of microcharcoal, reflecting fires, are 352 recorded in correspondence of high values of both *Erica* and *Q. ilex.* Contemporary high values of *Q.* 353 ilex and microcharcoal support the interpretation of Reille (1992a) and Carcaillet et al. (1997), which 354 suggest that the development of holm oak in Corsica was triggered by anthropogenic fires. At 355 Crovani, a substantial portion of the Mid-Holocene fires may be related to human activity, which is 356 witnessed by a significant presence of anthropogenic indicators (Figs 6-8). High frequencies of 357 microcharcoal in zones CRO-1 and CRO-2 are consistent with the coeval high incidence of fires 358 recorded in the region (Leys et al., 2014; Lestienne et al., 2020a, b), most of which are attributed to 359 human activity. According to Lestienne et al. (2020b), since 5000 cal. BP humans have taken control 360 of the fire regime through agro-pastoralism, favouring large and/or frequent fire events. For the same 361 reason, the marked decrease in microcharcoal recorded at Crovani during the Late Holocene after

- ~3350 cal. BP, which matches a decrease in anthropogenic pollen indicators, may reflect decreased
   human activity, at a time of an unsuitable climate for fires.
- Starting from ~2900 cal. BP, there was a general decline in *Erica*, opposed to an increase in holm oaks, which led to a turnover of the two woody taxa between 2300 and 1900 cal. BP. In this timeinterval, an increase in oaks may have been influenced by the forestry practices of Roman times. All the same, in the last ~2500 years, a clear development of cork oak in Corsica (Reille, 1984, 1992a), Sardinia (Di Rita and Melis, 2013), and the western Iberian Peninsula (Carrión et al., 2000) may be
- 369 related to silvicultural practices.
- Between 1900 and 1000 cal. BP (pollen zone CRO-6), a new moderate increase in *Erica* at the expense of *Q. ilex* suggests a new expansion of the native *Erica*-dominated shrublands.
- 372 Between 1000 and 500 cal. BP (pollen zone CRO-7), a major degradation of the forest cover is
- 373 recorded, with a massive decline of the tall *maquis* that was replaced by *Cistus*-dominated low 374 shrubland. After ~ 500 BP, *Erica* and *Q. ilex* recovered, as recorded also in other sites of Corsica (e.g.
- $S_{1}$  = sinubland. Then > 500 b1, *Erreu* and *Q. nex* recovered, as recorded also in other sites of consider (e.g.
- 375 Vella et al., 2019).
- 376 Modest oscillations of deciduous trees throughout the record (Fig. 6 and 8) suggest that they were 377 scarcely involved in the environmental processes influencing the evergreen vegetation, probably 378 because they were located at higher elevations in the island. Frequent finds of mesophilous trees such 379 as *Fagus* and *Betula*, which require temperate and humid conditions, confirm that part of the pollen 380 rain originated from the montane vegetation belt. The fingerprint of deciduous trees in the pollen 381 record of Crovani, as in other coastal pollen records of Corsica (Reille, 1992a; Currás et al., 2017; 382 Revelles et al., 2019), is clearly due the steep topography of the island, which determined a relatively 383 low distance of montane and sub-montane vegetation belts from the coast. However, it cannot be 384 excluded that sparse stands of mixed oak communities could also be preserved in humid areas at low 385 elevations, especially inside floodplain and riparian woodlands, dominated by Alnus, accompanied 386 by Salix, Tamarix, and possible wild Vitis, which are still documented in the area (Reille, 1992a).
- Conifers are mostly represented by *Pinus*, substantially reflecting the persistence of *Pinus nigra*subsp. *laricio* at montane and sub-montane elevations since the late glacial period (Leys et al. 2014).
  The occurrence of *Pinus pinaster* since the Bronze Age is probably related to human activity (Reille,
- 390 1992a). In addition to pine, conifers include taxa distributed in both lowland/coastal areas, such as
  391 *Juniperus*, and in montane sectors, such as *Abies* and *Taxus* (Fig. 7). Rare occurrences of *Picea*,
- 392 whose current natural range does not include Corsica, are of distant origin.
- 393
- 394
- 395

### 396 5.2. Environmental responses to hydrological and morphosedimentary processes

- 397 The local aquatic environment outlined by the pollen record ranged from brackish (6100-3400 cal. 398 BP) to freshwater conditions (~3400 cal. BP-present day) (Fig. 10). This range is documented by the 399 presence of freshwater taxa, such as Spirogyra, Zygnema and Myriophyllum, salt-tolerant species, 400 such as *Ruppia maritima*, and marine organisms, represented by foraminiferal linings, pointing to 401 inputs of salt-water into the pond (Bellotti et al., 2016). This was likely related to the morphological 402 response of the pond to the Mediterranean sea-level rise whose average rates decreased from ~2 mm a<sup>-1</sup> at ~6100 BP to less than ~0.5 mm a<sup>-1</sup> in the last 3500 years (Vacchi et al., 2021). These major 403 404 changes in the rising rates probably have an influence on the connection of the pond with the open 405 sea as already observed in lagoonal setting both in Corsica (e.g. Vacchi et al., 2017; Revelles et al., 406 2019) and in Sardinia (Melis et al., 2017, 2018). However, the absence of fossil faunal associations 407 hampered a detailed reconstruction of the nature of this backshore environment and its millennial 408 evolution.
- 409 The lower part of the record (~6100 to ~4800 cal. BP) is characterized by high frequencies of 410 Spiniferites sp. (Fig. 7), dinoflagellate cysts often difficult to identify at the species level by routine 411 observation in light microscopy (de Vernal et al 2018). The genus Spiniferites is characterized by 412 marine species, but it cannot be excluded that some Mediterranean species live in freshwater 413 environments (Kouli et al., 2001; Zonneveld et al., 2013). Based on pollen records obtained from 414 central Mediterranean regions, the presence of Spiniferites is often associated to brackish water (Di 415 Rita et al., 2018b). Irrespective of water salinity, high frequencies of *Spiniferites* in the lower part of 416 the Crovani sequence may reflect the pioneer stages of a hydrosere succession connected to the early
- 417 phases of development of the coastal pond.
- From ~4800 to ~3350 cal. BP (zone CRO-2), a significant increase in *Ruppia maritima*, a submerged angiosperm with large salinity tolerance (Kantrud, 1991), coupled with occurrences of foraminiferal linings, highlights a brackish environment. It is consistent with the observed presence of halite in unit VI (Fig. 4). Beds of submerged widgeongrass plants usually occur on muddy sand and mud in brackish pools. They accumulate sediment and may be associated with terrestrial saltmarsh plants, forming a hydrosere succession in coastal wetlands (Rodwell, 2000).
- 424 Starting from ~3350 cal. BP, the abrupt decrease in *Ruppia* and the disappearance of most spores of 425 fungi, coupled with a major increase in *Pseudoschizaea* (2%) and fern spores, are the results of 426 complex sedimentological and ecological changes leading to a lowering of the water level and to the 427 establishment of the present-day marshy environments. *Pseudoschizaea* suggests both desiccation 428 (Scott, 1992) and freshwater flows accompanied by erosive processes, sometimes associated with 429 runoff events (Pantaléon-Cano et al., 2003), while the disappearance of most fungal spores, the

- decrease in pollen concentrations, and the high percentages of Cichorioideae (Figs 6-8) can be
  interpreted as selective preservation of palynomorphs (Bottema, 1975; Havinga, 1984).
- 432 It is noteworthy that Reille (1992a) recorded a sharp drop in Ruppia at 150 cm depth and correlated 433 it with a local change in sediment accumulation. This was caused by an event of forest clearance, 434 followed by an increase in runoff, leading to the accumulation of a sandy layer and a significant 435 development of ferns. In our record, a phase of increased terrestrial runoff is revealed by an input of 436 organic matter of continental origin recorded by a positive excursion of C/N ratio at 1.36 m (ca. 3250 437 cal. BP - Fig. 4) and by a significant increase in detrital minerals (Fig. S1), but is not preceded by 438 clear changes in AP percentages that may testify to a deforestation process, although there is a drop 439 in AP concentrations around 3350 cal. BP. A clearance of local shrubs, represented by a sharp decline 440 in *Erica* frequencies, was recorded only after ~3100 cal. BP (Figs 6 and 8).
- 441 Summarizing, initially the opening of the vegetation did not change the composition of the shrubland, 442 which was later affected by the drop of *Erica*. Sedimentological analyses indicate an increase of the 443 granulometry within a broader context of swamp environment of deposition characterized by 444 homogeneous clays. At ~136 cm depth (ca. 3250 cal. BP), there is an event of higher energy of 445 deposition characterized by the punctual presence of coarse silts to fine sands. In the Canniccia pond, 446 located in SW Corsica, Ghilardi et al. (2017b) and Vella et al. (2019) identified a high detrital input 447 dated ca. 3350 cal. BP. At a regional scale, the southern France recorded an intense phase of 448 alluviation within the Rhone drainage basin (Berger et al., 2007) and the Pyrenean mountains (Galop 449 et al., 2007). This is possibly explained by the occurrence of a cooler and more arid period that resulted 450 in deforestation on a regional scale (Ghilardi et al., 2017a), recognized in western Mediterranean 451 pollen records (Carrión, 2002; Fletcher et al., 2013) and in speleothems from Tuscany located only 452 ca. 200 km from Crovani (Regattieri et al., 2014). However, the eastern coast of Corsica did not 453 record such event (Currás et al., 2017), which seems to have especially affected western Corsica.
- Since ~2900 cal. BP, an expansion of ferns and other hydrophytes (Fig. 7) suggests stagnant water, which may have been produced by a lowering of the lake enhanced by runoff, sediment infilling, and a salinity change towards more freshwater conditions. This change is confirmed by the observed decrease in the halite since the final part of units VI (Fig. 4). Such pattern is consistent with a substantial sea-level stability, which occurred in the NW Mediterranean Sea in the last ~2000 years (Vacchi et al., 2021). This stabilization process significantly decreased the salinity input within the pond triggering the progressive transition in pure freshwater environment.
- 461 Overall, the sequence dinoflagellates (*Spiniferites*)  $\rightarrow$  acquatic plants (*Ruppia maritima*)  $\rightarrow$  ferns 462 profiled throughout the pollen record corresponds to a hydrosere succession, whose evolution is 463 strictly related to the sediment infilling of lakes (Fig. 6). This ecological succession typically involves

reed swamp vegetation at an intermediate stage, here represented by pollen of Cyperaceae and partly of Poaceae, and *Alnus* at a mature stage. In several coastal sedimentary archives of the central Mediterranean, temporary expansions of Cyperaceae and Poaceae are followed by an increase in *Alnus* (Magri et al., 2019 and references therein). At Crovani this pattern is especially clear in the interval between ~2600 and ~1700 cal. BP, when complete hydrosere succession with a climax woodland stage occurred in marginal sectors of the basin, in relation to a lagoon reduction (Fig. 6).

470

# 471 *5.3. Human impact on the landscape*

472 Human activity is evident throughout the pollen record with different intensity and type of land use
473 (Fig. 10). During the Late Neolithic, from ~3900 to ~3250 BC, the continuous curve of cereal-type

474 pollen testifies to early cultivations (Fig. 6). Evidence for agriculture is also observed at the Saint

475 Florent site starting from ~4000 cal. BC (Revelles et al., 2019), but only the extreme south of the

476 island (Bonifacio-Piantarella area) exhibits continuous agricultural practices all along the Neolithic

477 period. At Crovani, the pollen record reveals human activity older than the archaeological finds,

- indicating that farming was practiced ~1000 years before the earliest trace of human occupation at
- 479 the Teghja di Linu site (Sicurani and Martinet, 2019).

480 Cereal cultivation appears associated to livestock rearing activities, which contributed to the 481 development of disturbed meadows, as highlighted by a significant record of Sporormiella, Sordaria, 482 and Podospora, and by pollen indicators for Mediterranean pasturelands, such as Carduus-type, 483 *Plantago*, *Polygonum aviculare*-type, as well as some species of the subfamilies Asteroideae and 484 Cichorioideae (Desprat et al., 2013; Florenzano et al., 2015) (Figs 6 and 8). The high values of 485 microcharcoal may partly reflect the use of fire for farming purposes, such as slash-and-burn 486 practices, which however did not affect the fire-adapted local shrubland. In general, human activity 487 during the Late Neolithic certainly influenced the vegetation evolution of the area, but its impact did 488 not produce a marked local deforestation. While we cannot advance any precise explanation for this 489 pattern, we can speculate that local settlements were not populated enough to produce forest declines 490 detectable in the pollen diagram.

491 During the Final Neolithic and Bronze Age (from ~3000 to ~800 BC), both cereal cultivation and 492 livestock rearing appear less intense and discontinuous. The archaeological history of Corsica 493 indicates that Early to Middle Bronze Age are periods of human implantation in the upper part of the 494 hills (Casteddi) when lowlands and coastal areas were less occupied (Cesari and Pêche Quilichini, 495 2015). The pollen record from Crovani confirms this pattern, even if in some coastal areas the Mid-

496 to Late Bronze Age corresponds to a phase of renewed agriculture (Ghilardi et al., 2017a).

- In the Iron Age, cereals disappeared and scattered occurrences of pasture weeds (e.g., *Carduus*, *Plantago*, and *Rumex*) testify to poor farming practices addressed to livestock rearing, suggesting a
  scarce human frequentation in the area (Fig. 6).
- Human activity at Crovani is also revealed by the record of cultivated trees (OJCV curve, Fig. 8),
  which also include pollen of wild individuals of *Olea* and *Vitis* that is difficult to differentiate from
- 502 pollen of cultivated plants (Reille, 1992a).
- 503 In the period encompassing the Neolithic to the Bronze Age the pollen record of Crovani shows some 504 early occurrences of Juglans (ca. 3700 BC) and Castanea (ca. 1200 BC) (Fig. 6). Similar early finds 505 are also recorded in pollen diagrams from recently published coastal sites (Poher et al., 2017; Currás 506 et al., 2017; Revelles et al., 2019). Although these occurrences are generally found during phases of 507 intense human activity, as confirmed by the presence of other anthropogenic pollen indicators, it is 508 difficult to hypothesize that cultivation of these trees was such early, without a clear archaeobotanical 509 evidence. Unfortunately, the palynological studies of Reille (1992a; 1999) and Lestienne (2020a) do 510 not contribute to solve this question, since their records do not show any Castanea and Juglans before 511 2500 cal. BP. They interpret these finds as a result of cultivation in the island in historical times. In 512 addition, the absence of palynological investigations from Pleistocene sediments prevents us to 513 speculate on a possible redeposition of pollen from older deposits. We would exclude a long-distance 514 origin, especially for Juglans, whose pollen dispersal occurs over short distance despite its renowned 515 anemophily (Carrión and Sánchez-Gómez, 1992).
- 516 Phylogeographical studies demonstrate that the post-glacial distribution of chestnut and walnut in 517 Europe and in the Mediterranean regions started from multiple glacial refugia (Mattioni et al., 2013; 518 Pollegioni et al., 2017). However, due to both the scarcity of palaeobotanical knowledge and 519 incomplete genetic sampling, as in the case of Corsica and Sardinia, there is still much uncertainty in 520 detecting glacial refugia and drawing up robust biogeographical histories of cultivated trees (Médail 521 et al., 2019).
- 522 In historical time, the OJCV record shows two major phases of tree cultivation. The first one, between 523 ~250 BC and ~150 AD, reflects a widespread exploitation of olive resources during the Roman 524 Period, also documented by archaeological evidence (Terral et al., 2004). The second increase, after 525 ~1450 AD, testifies to an intensification of *Olea* cultivation and a regional plantation of *Castanea* in the uplands. From 1548 until the 17<sup>th</sup> century, the Genoese Authority introduced the compulsory 526 527 cultivation of chestnut, whose fingerprint in the Crovani record is represented by a peak of Castanea 528 (Fig. 6) (Michon, 2011). The consequence of this decree was a large reorganization of the food, 529 economy, and socio-cultural systems, as shepherds slowly became chestnut growers and settled more permanently in mid-mountain villages. The chestnut culture fully developed during the 18th and 19th 530

centuries, providing flour for daily meals, fodder for animals, and fruits for trade. By the end of the
19<sup>th</sup> century, the development of local industries and the related outflow of rural population toward
urban centres determined the collapse of the chestnut culture (Michon, 2011).

534 Human impact on the forest cover is recorded since ~1000 BC (Final Bronze Age), mostly by 535 decreases in evergreen trees and shrubs staggered over time (Fig. 8), coupled with increases in both 536 herbaceous vegetation and *Cistus* dominated low shrublands (Figs 6 and 8). Considering the local 537 modest farming practices of the last three millennia, this pattern may mostly reflect clearance practices of the Erica shrubland at a regional scale. This is consistent with the human-induced 538 539 opening of the forests recorded in several other pollen sites of Corsica (Reille, 1992a; Revelles et al., 540 2019; Lestienne et al., 2020a), and in coastal sites of the central Mediterranean since ~1000 cal. BC 541 (Di Rita and Magri, 2012). According to Roberts et al. (2019), after ~1000 BC human activity became

the dominant causation in determining landscape openings in the Mediterranean regions

543 Despite clear land use changes are recorded, human activities at Crovani did not completely transform 544 the structure of the vegetation in terms of forest canopy, except for a temporary dramatic drop of the 545 maquis vegetation between 950 and 1450 AD (1000-500 cal. BP), for which a prominent anthropogenic causation cannot be ruled out. Pollen indicators of human activity are scarce in this 546 547 period, but the reappearance of coprophilous fungi (Sporormiella) and the increase in Castanea and 548 *Olea*, together with a slight increase in fire frequency, may reflect silvicultural practices addressed to 549 the felling of shrublands to gain land available for both stock rearing and olive cultivation in the 550 lowlands, as well as for chestnut cultivation in the uplands. A similar observation was advanced in 551 the Saint-Florent area, where an important deforestation phase was coeval to the development of 552 pastoral activities (Revelles et al., 2019). Between ~1000 and ~500 cal. BP, also frequencies >2% of 553 Pseudoschizaea and Glomus support soil erosion and local deforestation (Figs 7 and 10). This was 554 also the time when several churches were locally built (Fig. 1A).

555 The human activities may also be tracked from the Pb isotope signature of the Crovani sediments. 556 The sedimentary Pb data are aligned along a linear trend in a binary <sup>208</sup>Pb/<sup>206</sup>Pb - <sup>206</sup>Pb/<sup>207</sup>Pb diagram 557 (Fig. 5A and B). Such distribution indicates a mixing between two end-members, a natural end-558 member with higher isotope Pb ratios and a probable anthropogenic-derived end-member 559 characterised by lower isotope ratios.

(a) The first end-member has been defined by the average signature of 3 samples dated from the Final Neolithic period (196 to 260 cm). They are used to define the local detrital source with low isotopes ratios (i.e.,  ${}^{208}\text{Pb}/{}^{204}\text{Pb} = 38.9584 \pm 0.0020$ ,  ${}^{207}\text{Pb}/{}^{204}\text{Pb} = {}^{206}\text{Pb}/{}^{204}\text{Pb}$  15,6719 ± 0.0008 and  ${}^{206}\text{Pb}/{}^{204}\text{Pb} = 19,0775 \pm 0.0008$ ) (Table S1). This end-member represents the natural background endmember. The composition of the samples corresponding to the Iron Age, only defined by 2 measurements, is slightly different from the previous Bronze Age and Final Neolithic periods, with a position closer to the sample from the Roman representative average. The Pb isotope ratios of the sediments roughly decrease upwards from the natural background end-member. The oldest pre-Roman samples (n= 19, 93-260 cm) are clustered with an average signature of 38.9667  $\pm$  0.0235, 15.6716  $\pm$  0.0007 and 19.0702  $\pm$  0.0008 for <sup>208</sup>Pb/<sup>204</sup>Pb, <sup>207</sup>Pb/<sup>204</sup>Pb and <sup>206</sup>Pb/<sup>204</sup>Pb, respectively.

570 (b) A shift towards lower Pb isotope ratios is marked for the Roman samples (53 and 73 cm) and 571 for the modern samples (11-23 cm). The first Roman shift may be related to some exploitation of Pb 572 ores. The isotope composition of both regional Pb-bearing ores and modern urban airborne particles 573 (Bollhöfer and Rosman, 2001) are reported in order to confirm any anthropogenic contribution in the 574 sediment Pb isotope composition. The isotope Pb ratios of the Roman and modern samples become 575 closer and closer to the Corsican Pb minerals (Fig. 5). The analysed Pb-bearing minerals display close Pb isotope signatures, with an average composition of 1.1779 for <sup>206</sup>Pb/<sup>207</sup>Pb and 2.0894 for 576 <sup>208</sup>Pb/<sup>206</sup>Pb. The first decrease of the Pb isotopic ratio observed in the Roman Crovani sediments is 577 578 in agreement with the historical exploitation of the Pb-Ag ores from the Argentella during the Roman 579 period (Gauthier, 2006). The linear trend defined by the modern samples does not point towards the 580 modern urban airborne particles but rather towards the Pb signature of the Sardinian ores (Stos-Gale 581 et al., 1995). In the Crovani sediments, Sardinia seems to be the most probable anthropogenic source 582 of Pb among the main Pb mines exploited in the Mediterranean area, i.e. in Greece, Turkey, Italy and Spain since the Antiquity (see more details in Fagel et al., 2017). In the binary <sup>206</sup>Pb/<sup>207</sup>Pb-<sup>208</sup>Pb/<sup>206</sup>Pb 583 584 diagram, the Crovani samples define a linear trend that, if extrapolated, points to the representative 585 average signature of Sardinian ores (Fig. 5 B).

586

# 587 5.4. Effects of Rapid Climate Changes on the coastal tree-cover

In the palaeobotanical narrative of Corsica, no clear tree-cover change has ever been attributed to a "Bond event" (Bond et al., 2001) (Fig. 8) or other RCC of global interest, such as the 4.2 ka event (Bini et al., 2019), the Homeric minimum (2.8 ka BP) (Martin-Puertas et al., 2012) and the Little Ice Age (Trouet et al., 2009). These events have produced major changes in forest cover in many sites of central and western Mediterranean regions, although with contrasting trends (Fletcher et al., 2013, Magny et al., 2013; Di Rita et al., 2018a).

- 594 The 4.2 cal. BP event, perceived in south-central Italy as an aridity crisis producing a forest decline,
- 595 did not trigger a rapid response in the regional forest vegetation in Corsica and in the northern
- 596 Apennines (Di Rita and Magri, 2019; Revelles et al., 2019; Di Rita et al., 2022). However, previous
- 597 studies in Corsica have shown that the 4.2 event played an influence on geomorphological and
- 598 sedimentological processes, due to increased storm and fluvial activities as recorded in several lagoon

- 599 archives (Revelles et al., 2019 and references therein). In our record from Crovani, rapid fluctuations 600 of the forest cover are found, marked by maximum values of AP (92%) at ca. 4450 cal. BP (Figs 6 601 and 8). Between 4700 and 3500 cal. BP, a long-lasting increase in Fagus suggests permanent humid 602 conditions during the Mid- to Late Holocene transition (Fig. 6), which are recorded also in other 603 montane sites (Reille, 1975; Reille et al., 1999) and pollen sequences from coastal Corsica (Poher et 604 al., 2017; Revelles at al., 2019). The development of beech corresponds to relatively wet climatic 605 conditions in central Italy, as revealed by lake level highstands at Lake Accesa ca. 160 km far from 606 Crovani (Magny et al., 2013). Lake level highstands reflecting humid conditions are also recorded in 607 northern Italy (cf. Lake Ledro: Magny et al., 2012), and in west-central Europe (Magny et al., 2013) 608 and references therein).
- 609 The development of beech corresponds also to periods of increased storm activity in southern France
- 610 (Sabatier et al., 2012) (Fig. 8). Although these periods were previously interpreted as a result of
- 611 southward westerly winds bringing moisture to mid-latitudes in Europe (Sabatier et al., 2012; Magny
- 612 et al., 2013), they may also reflect an increase in the frequency of marine storms that are not directly
- 613 interpretable as periods of regional increased precipitation (Azuara et al., 2020). An alkenone record
- from the Gulf of Lion suggests moisture increase in southern France since ca. 4200 cal. BP (Jalali et
  al., 2017; Azuara et al., 2020).,
- 616 The general pattern of increased humidity in western Corsica contrasts with the drier conditions
- 617 indicated by precipitation proxies from the speleothems of the Corchia and Renella caves in Tuscany
- 618 (Zanchetta et al., 2016; Isola et al., 2019), and depicts a complex geographic expression of the 4.2 ka
- 619 event (Bini et al., 2019; Di Rita and Magri, 2019; Di Rita et al., 2022).
- 620 The Homeric Minimum (2750-2550 cal. BP, Martin-Puertas et al., 2012) was associated to forest 621 declines influenced by human impact and dryer climate conditions in many records of the southcentral Mediterranean (Di Rita et al., 2018c). At Crovani, it corresponds to a modest peak in AP, 622 623 possibly related to slightly wetter conditions. Relatively higher precipitations were recorded from 624 lake-level highstands since 2800 cal. BP at Lake Accesa (Fig 8), and from lake-level highstands and 625 pollen evidence at Lake Ledro (Magny et al., 2012; Peyron et al., 2017). More humid climate 626 conditions were also found in the western Mediterranean, possibly associated to the negative NAO 627 index that characterizes this interval (Fletcher et al., 2013). This phase corresponds also to increased 628 storm activity in the Gulf of Lion (Sabatier et al., 2012).
- 629 During the Little Ice Age, the record of Crovani shows a marked increase in *Erica* and *Q. ilex maquis*,
- 630 accompanied by significant frequencies of cultivated trees related to orchards and conifer plantations
- 631 (Figs 6 and 8). The development of natural and cultivated woody taxa was probably favoured by
- 632 relatively wet climate conditions, which were also recorded in both central and northern Italy from

- lake-level highstands (Magny et al., 2013), as well as in southern France from records of major
  flooding (Benito et al., 2015, Pichard et al., 2017), coinciding with a mostly negative NAO index
  (Franke et al., 2017) (Figs 8 and 10). Climate reconstructions in Corsica are still fragmentary,
  however the few published studies indicate the occurrence of periods characterized by wet and cool
- 637 conditions (Szymczak et al., 2012; Vella et al., 2014).
- 638 The archaeological and paleoenvironmental literature does not provide noticeable examples of rapid 639 and dry climate events in Corsica. As previously discussed, the complex sedimentological pattern at 640 ~3250. cal. BP (Fig. 4) might be related to an arid climate event observed around the same age in 641 other palaeoenvironmental records. Relatively dry and warm climate conditions may have also 642 contributed to produce the major forest decline recorded between 1000 and 500 cal. BP, limiting the 643 resprout of the natural forest vegetation affected by felling activities. In the western Mediterranean, 644 the dry and warm climate of the Medieval Climate Anomaly is usually associated to an overall 645 positive NAO index (Trouet et al., 2009; Franke et al., 2017) (Fig. 8).
- 646 Sabatier et al. (2020) have found a strong relationship between the transport of Saharan dust conveyed 647 to Corsica during the last ~3000 years and both total solar irradiance (TSI) and NAO activity. They 648 have shown that the NAO was the main climatic forcing for centennial to decadal variations since 649 ~1070 AD, with an increase in Saharan dust input during positive NAO phases. Before ~1070 AD, 650 TSI was the main forcing factor, with increases in African dust input during low TSI phases.
- 651 We applied a REDFIT analysis to the total AP percentages to investigate the effects of the 652 atmospheric circulation on the tree cover record from Crovani (Fig. 9). The prominent 230-year cycle 653 found in our statistical elaboration by and large corresponds to the Suess-de Vries cycle of solar 654 activity, which has been held responsible for environmental and atmospheric changes in several 655 records around the world, including the Mediterranean (Castagnoli et al., 1992; Galloway et al., 2013; 656 Di Rita, 2013; Degeai et al., 2014; Sabatier et al., 2020). The Suess-de Vries cycle is commonly 657 identified as a conventional 210-year periodicity; however, an increasing number of studies 658 demonstrates its non-stationary variability, which may have a range of ~200-300 years (Vecchio et 659 al., 2017). Similarly, its expression in palaeoenvironment proxies shows a non-stationary periodicity
- (Galloway et al., 2013). A 230-year cycle was detected in direct proxies of solar magnetic activity,
   such as <sup>14</sup>C time series and naked-eye observations of sunspots (Ma and Vaquero, 2020).
- The REDFIT analysis from Crovani shows also two periodicities of ca. 430 and 1000 years, respectively (Fig. 9). The first one corresponds to the ca. 430-years and 450-year cycles detected by Sabatier et al. (2020) in the records of Saharan dust in Corsica, as shown by both TSI and ITCZ, although the authors attribute a low significance to this cycle. A 440-year cycle (together with a 230year cycle) was found in  $\delta^{13}$ C records of speleothems from northern Iberia and was interpreted as the

result of climate forcing mechanisms related to changes in solar irradiance and North Atlantic circulation patterns (Mártin-Chivelet et al., 2011). Periodicities of ~400-years were recognized in various palaeoclimate proxies from both marine (e.g., Bond et al., 2001) and lake records (e.g., Yu and Ito, 2002; Wu et al., 2009) of the Middle-Late Holocene.

The last periodicity we found at Crovani matches a prominent ~1000-year cycle of moisture supply reported in proxy records from the western Mediterranean, especially during the Early Holocene, which have been associated to solar activity (Debret et al., 2009; Fletcher et al., 2013; Jiménez Moreno et al., 2020 and references therein).

Overall, our results show that the forest oscillations at Crovani present a fundamental tempo of variability consistent with the atmospheric forcing held responsible for the transport of Saharan dust to Corsica. Although the relationship between solar activity and forest dynamics in Corsica is only sketched, our findings encourage future research in the central Mediterranean, interpreted in the light of the regional patterns of vegetation change.

680

#### 681 5.5. Coastal landscape evolution of the Crovani area

682 Based on the cross combination of sedimentological, palynological and geochemical proxies, we 683 propose a synthetic palaeogeographical reconstruction of the investigated area, even if additional 684 cores would be necessary to evaluate in a comprehensive way both the morphological changes and 685 the spatial evolution of the Crovani wetland since the Mid-Holocene. The bottom of the core records 686 a detrital environment with a mixture of well-rounded pebbles and coarse material, ranging from 687 sands to gravels. Unfortunately, this section of the core did not contain enough organic material for 688 obtaining a radiocarbon age. Furthermore, facies identification was difficult due to the lack of fossil 689 fauna. However, on the basis of the sedimentological information, two types of energy of deposition 690 can be identified. The first is controlled by terrestrial dynamics being characterized by the finest 691 particles (grey clays). The second is conversely controlled by coastal dynamics as indicated by the 692 presence of well-rounded pebbles that are analogue in shape and petrography to the sediments which 693 compose the modern coastal barrier. These data suggest that the continental dynamics likely prevailed 694 during the first half of the Holocene. This was followed by a mid-Holocene marine transgression that 695 reached its maximum ~6500 cal. BP, when the sea-level in Corsica was ca. 3.5 to 4 m below the 696 present-day position (Vacchi et al., 2018). At that time, which broadly correspond to Middle to Late 697 Neolithic, a marine incursion occurred in the Crovani coastal pond following a pattern that was also 698 observed in other coastal lagoons in Corsica, such as Saint Florent (Revelles et al., 2019) and Del 699 Sale (Curras et al., 2017). As a result, the pond turned into brackish conditions after ~6100 cal. BP, 700 as confirmed by the presence of *Spiniferites*, which substantially indicates a connection with the sea

701 (Fig. 6 and 10). However, probably due to the presence of Late Pleistocene alluvial formations and 702 relict coastal deposits (former coastal barriers), the marine incursion inland was spatially limited. This 703 could explain the lack of faunal assemblages typical of coastal lagoon made by ostracods, 704 foraminifera and molluscs faunas. After ~5100 cal. BP, during the Late to Final Neolithic 705 characterized by the first occupation of the nearby site of Teghja di Linu, data show detrital input that 706 suddenly modified the brackish conditions of the pond. However, our data indicates that nor a climate 707 event neither human impact provoked deforestation associated to intense erosion on the foothills and 708 sedimentary accumulation of coarse material, even if there is a clear land-use at that time (Fig. 10). 709 A second phase of wetland development is well attested from the Final Neolithic to Middle/Recent 710 Bronze Age. Presence of salt intrusion is confirmed by both the vegetation composition and the 711 geochemical analyses (presence of halite) but there is no clear evidence for a direct of the coastal 712 pond connection to the sea (e.g., presence of faunal assemblages typical of coastal lagoons). A second 713 detrital input is observed during the Late Bronze Age (Unit VII). The C/N Ratio exhibits the highest 714 values for the entire sequence studied, thus indicating a terrestrial deposition of organic matter (see 715 section 4.2.) (Fig. 4). This is likely a rapid event (not more than a century in duration) that could have 716 caused the silting up of the wetland. Finally, the present-day landscape configuration is established 717 since Final Bronze Age (unit VIII) with very little morphological changes afterwards. Since ~3200 718 cal. BP, Crovani coastal pond has been a backshore freshwater body with probable aeolian input of 719 salt, no permanent connection to the sea, and low sediment accumulation rate (Fig. 10).

720

### 721

## 722 6. Conclusions

The new multidisciplinary dataset obtained from northwest Corsica helps to reconstruct the past environmental dynamics (Fig. 10) within an archaeological context, and to frame it into the wider scenario of the central Mediterranean landscape evolution. Our results contribute to the lively discussion on the vegetation response to rapid climate changes, raising also new questions about planetary drivers of past atmospheric circulation and their possible influence on the forested ecosystems of this strategic region of the Mediterranean. In particular, the following conclusions can be traced:

A dense *Erica*-dominated shrubland rich in many evergreen elements characterized the
 landscape from ~6100 to ~1000 cal. BP, being temporarily replaced by mixed woodlands
 dominated by *Q. ilex* between 2300 and 1900 cal. BP. A major opening of the landscape occurred
 only between ~1000 and ~500 cal. BP, featured by a temporary decline in *Erica*-dominated tall

shrublands, paralleled by an expansion of *Cistus*-dominated low shrublands and followed by the
recovery of the tall *maquis* formations.

2) Fires played a prominent role in the development and maintenance of the *Erica*-dominated
shrublands, especially during the Middle Holocene (from ~5900 to ~5200 cal. BP), when frequent
and intense wild and anthropogenic fires boosted the sprout of *Erica* species. Differently from
other sites in Corsica and Sardinia, at Crovani fires did not affect *Q. ilex*, whose development
cannot be univocally explained in the region and may be influenced by a long-lasting ecological
legacy. The general decrease of fires after ~3300 cal. BP may reflect a combination of decreased
human activity and climate unsuitable for fires.

743 3) The Crovani wetland has been little influenced by marine incursions over the last six 744 millennia, as indicated by sedimentological data, pollen and NPPs. Moderate brackish conditions 745 occurred only from the Late Neolithic to part of the Bronze Age, while during the last three 746 millennia general freshwater conditions prevailed. The sequential development of dinoflagellates, 747 *Ruppia*, and ferns appears to reflect a hydrosere succession, whose evolution is strictly related to 748 the infilling of the lake. After ~3300 cal. BP, this ecological process was influenced by a sudden 749 deposition of continental organic-rich sediments, following rapid deforestation and runoff of 750 regional extension, coeval to an arid climate event occurred around ~3200 cal. BP.

751 4) Evidence for human activity is present throughout the pollen record, with important 752 differences through time. Between ~6000 and ~5200 cal. BP, a continuous curve of cereal-type 753 pollen testifies to the earliest cultivations in this area. Farming activities are also confirmed by the 754 presence of disturbed meadows for livestock rearing, indicated by coprophilous fungi and pollen 755 indicators of plants frequently living in Mediterranean pasturelands. Starting around 3300 cal. BP, 756 indicators of cereal cultivation and stock rearing practices became sparse, and evidence for human 757 activity comes from cultivated trees, especially after ca. 2000 cal. BP and even more after ~500 758 cal. BP. The former increase reflects olive exploitation during the Roman Period, the latter points 759 to both olive cultivation in lowland areas and chestnut culture in the uplands. A clear forest 760 degradation dates back to the last three millennia, with a dramatic opening of the landscape only 761 from ~1000 to ~500 cal. BP, related to human activity in the medieval times and Genovese domination. 762

5) The spectral analysis applied to total AP revealed a ~230-year cycle, in the bandwidth of the Suess-de Vries cycle, and other cyclicities attributed to the magnetic activity of the Sun, recognized also in other climate proxies from the Mediterranean. This suggests that the atmospheric modifications of solar activity and North Atlantic Oscillation had some influence on the tree cover fluctuations in Corsica. However, known rapid climate changes, such as the 4.2 ka

- 768BP event, the Homeric minimum, and the Little Ice Age, did not determine at Crovani extensive
- 769 forest declines as they did in sites of the south-central Mediterranean. In contrast, in northwestern
- 770 Corsica these phases correspond to a forest development consistent with the humid phases detected
- in southern France and northern Italy. The high-resolution record from Crovani is an important
- piece of information to define the spatial pattern of vegetation response to the atmospheric
- arrangements produced by rapid climate changes over the Mediterranean Basin during the
- Holocene.
- 775

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- 789 **Reference list**
- 790 791 Azuara, J., Sabatier, P., Lebreton, V., Jalali, B., Sicre, M.-A., Dezileau, L., Bassetti, M.-A., Frigola, 792 J., Combourieu-Nebout, N., 2020. Mid- to Late-Holocene Mediterranean climate variability: 793 contribution of multi-proxy and multi-sequence comparison using wavelet spectral analysis 794 in the northwestern Mediterranean basin. Earth Sci. Rev. 208. 103232. 795 https://doi.org/10.1016/j.earscirev.2020.103232.
- Beffa, G., Pedrotta, T., Colombaroli, D., Henne, P.D., van Leeuwen, J.F.N., Süsstrunk, P.,
  Kaltenrieder, P., Adolf, C., Vogel, H., Pasta, S., Anselmetti, F.S., Gobet, E., Tinner, W., 2016.
  Vegetation and fire history of coastal north-eastern Sardinia (Italy) underchanging Holocene
  climates and land use. Veg. Hist. Archaeobotany 25, 271-289
- Bellotti, P., Calderoni, G., Di Rita, F., D'Orefice, M., D'Amico, C., Esu, D., Magri, D., Preite
  Martinez, M., Tortora, P., Valeri, P., 2011. The Tiber river delta plain (central Italy): coastal
  evolution and implications for the ancient Roman Ostia settlement. Holocene 21, 1105-1116.
- Benito, G., Macklin, M. G., Zielhofer, C., Jones, A. F., Machado, M. J., 2015. Holocene flooding and
   climate change in the Mediterranean. Catena 130, 13-33.
- Bengtsson, L., Enell, M., 1986. Chemical analysis, in: Berglund, B. E. (ed.), Handbook of Holocene
   Palaeoecology and Palaeohydrology. John Wiley & Sons Ldt., Chichester, 423–451.
- Bennett, K., 2009. "psimpoll" and "pscomb": CPrograms for Analysing Pollen Data and Plotting
   Pollen Diagrams (Version 4.27). Available online from Queen's University Quaternary
   Geology program at URL. http://www.chrono.qub.ac.uk/psimpoll/psimpoll.html.
- Berger, J.F., Brochier, J.L., Vital, J., Delhon, C., Thiebault, S., 2007. Nouveau regard sur la dynamique des paysages et l'occupation humaine à l'Âge du bronze en moyenne vallée du Rhône, in: Mordant C., Richard H., Magny M. (Eds.), Environnements et cultures à l'âge du Bronze en Europe occidentale. Actes du 129e colloque du CTHS, Besançon, avril 2004, Editions du CTHS, Documents Préhistoriques 21, 260-283.
- Beug, H., 2004. Leitfaden der Pollenbestimmung für Mitteleuropaund angrenzende Gebiete. Verlag
   Dr. Friederich Pfeil, München.
- Bini, M., Zanchetta, G., Perşoiu, A., Cartier, R., Català, A., Cacho, I., Dean, J.R., Di Rita, F.,
  Drysdale, R.N., Finnè, M., Isola, I., Jalali, B., Lirer, F., Magri, D., Masi, A., Marks, L.,
  Mercuri, A.M., Peyron, O., Sadori, L., Sicre, M.-A., Welc, F., Zielhofer, C., Brisset, E., 2019.
  The 4.2 ka BP Event in the Mediterranean region: an overview. Clim. Past 15, 555-577.
- Birks, H.J.B., Line, J.M., 1992. The use of rarefaction analysis for estimating palynological richness
   from Quaternary pollen-analytical data. The Holocene 2, 1-10.
- Blaauw, M., Christen, J. A., 2011. Flexible paleoclimate age-depth models using an autoregressive
   gamma process. Bayesian analysis 6, 457-474.
- Bollhöfer, A., Rosman, K.J.R., 2001. Isotopic source signature for atmospheric lead: the Northern
  Hemisphere. Geochim. Cosmochim. Acta 65, 1727-1740.
- Bond, G., Kromer, B., Beer, J., Muscheler, R., Evans, M.N., Showers, W., Hoffmann, S., Lotti-Bond,
  R., Hajdas, I., Bonani, G., 2001. Persistent solar influence on North Atlantic climate during
  the Holocene. Science 294, 2130-2136.
- Bottema, S., 1975. The interpretation of pollen spectra fromprehistoric settlements (with special attention to Liguliflorae). Palaeohistoria 17, 17-35.
- Carcaillet, C., Barakat, H. N., Panaïotis, C., Loisel, R., 1997. Fire and late- Holocene expansion of
   *Quercus ilex* and *Pinus pinaster* on Corsica. J. Veg. Sci. 8, 85-94.
- Carrión, J.S., 2002. Patterns and processes of Late Quaternary environmental change in a montane
   region of southwestern Europe. Quaternary Sci. Rev. 21, 2047-2066.
- Carrión, J.S., Sánchez-Gómez, P., 1992. Palynological data in support of the survival of walnut
   (*Juglans regia* L.) in the western Mediterranean area during last glacial times. J. Biogeogr.
   19, 623-630.

- Carrión, J.S., Parra, I., Navarro, C., Munuera, M., 2000. Past distribution and ecology of the cork oak
   (*Quercus suber*) in the Iberian Peninsula: a pollen-analytical approach. Divers. Distrib. 6, 29 44.
- Castagnoli, G.C., Bonino, G., Serio, M., Sonnett, C.P., 1992. Common spectral features in the 5500year record of total carbonate in sea sediments and radiocarbon in tree rings. Radiocarbon 34,
  798–805.
- Caudullo, G., Tinner, W., de Rigo, D., 2016. *Picea abies* in Europe: distribution, habitat, usage and threats. In: San-Miguel-Ayanz, J., de Rigo, D., Caudullo, G., Houston Durrant, T., Mauri, A. (Eds.), European Atlas of Forest Tree Species. Publications Office of the European Union, Luxembourg e012300b
- Cesari, J., Pêche-Quilichini, K., 2015. L'âge du Bronze corse. L'émergence d'une élite guerrière, in
  Leandri F., Istria D. (coord.), Corse, richesses archéologiques de la Préhistoire à l'époque
  moderne. Dossiers d'archéologie, 370, 24-29
- Clark, R.L., 1982. Point count estimation of charcoal in pollen preparations and thin sections of
   sediments. Pollen Spores 24, 523–535.
- Colombaroli, D., Tinner, W., Leeuwen, J. van, Noti, R., Vescovi, E., Vanniere, B., Magny, M.,
  Schmidt, R., Bugmann, H., 2009. Response of broadleaved evergreen Mediterranean forest
  vegetation to fire disturbance during the Holocene: in-sights from the peri-Adriatic region. J.
  Biogeogr. 36, 314-326.
- Cook, H.E., Johnson, P.D., Matti, J.C., Zemmels, I., 1975. Methods of sample preparation and X-ray
  diffraction analysis in X-ray mineralogy laboratory, in: Kaneps, A.G., et al. (Eds.), Init. Repts
  DSDP XXVIII. Print. Office, Washington DC, pp. 997-1007.
- Cugny, C., Mazier, F., Galop, D., 2010. Modern and fossil non-pollen palynomorphs from the Basque
   mountains (western Pyrenees, France): the use of coprophilous fungi to reconstruct pastoral
   activity. Veg. Hist. Archaeobot. 19, 391–408.
- 864 Currás, A., Ghilardi, M., Peche-Quilichini, K., Fagel, N., Vacchi, M., Delanghe, D., Contreras, D.,
  865 Vella, C., Ottaviani, J.C., 2017. Reconstructing past landscapes of the eastern plain of Corsica
  866 (NW Mediterranean) during the last 6000 years based on molluscan, sedimentological and
  867 palynological analyses. J. Archaeol. Sci.: Report 12, 755-769.
- B68 D'Anna, A., Marchesi, H., Tramoni, P., Gilabert, C., Demouche, F., 2001. Renaghju (Sartène, CorseB69 du-Sud), un habitat de plein-air néolithique ancien en Corse. Bulletin de la Société
  B70 préhistorique française 98, 431-444.
- Bean, W.E. Jr., 1974. Determination of carbonate and organic matter in calcareous sediments and
   sedimentary rocks by loss on ignition: Comparison with other methods. J. Sed. Petrol. 44:
   242–248
- Bebret, M., Sebag, D., Crosta, X., Massei, N., Petit, J.R., Chapron, E., Bout-Roumazeilles, V., 2009.
  Evidence from wavelet analysis for a mid-Holocene transition in global climate forcing. Quat.
  Sci. Rev. 28, 2675-2688.
- Begeai, J.P., Devillers, B., Dezileau, L., Oueslati, H., Bony, G., 2015. Major storm periods and
  climate forcing in the Western Mediterranean during the Late Holocene. Quaternary Sci. Rev.
  129, 37-56.
- Besprat, S., Combourieu-Nebout, N., Essallami, L., Sicre, M.A., Dormoy, I., Peyron, O., Siani, G.,
  Bout Roumazeilles, V., Turon, J.L., 2013. Deglacial and Holocene vegetation and climatic
  changes in the southern Central Mediterranean from a direct landesea correlation. Clim. Past
  9, 767-787.
- de Vernal, A., Eynaud, F., Henry, M., Limoges, A., Londeix, L., Matthiessen, J., Marret, F.,
  Pospelova, V., Radi, T., Rochon, A., Van Nieuwenhove, N., Zaragosi, S., 2018. Distribution
  and (palaeo)ecological affinities of the main *Spiniferites* taxa in the mid–high latitudes of the
  Northern Hemisphere. Palynology 42, 182–202.
- Bi Rita, F., 2013. A possible solar pacemaker for Holocene fluctuations of a saltmarsh in southern
  Italy. Quatern. Int. 288, 239-248.

- Bi Rita, F., Magri, D., 2012. An overview of the Holocene vegetation history from the central
   Mediterranean coasts. J. Mediterr. Earth Sci. 4, 35-52.
- Bi Rita, F., Magri, D., 2019. The 4.2 ka event in the vegetation record of the central Mediterranean.
   Clim. Past 15, 237-251.
- Bi Rita, F., Melis, R.T., 2013. The cultural landscape near the ancient city of Tharros (central West
   Sardinia): vegetation changes and human impact. J. Archaeol. Sci. 40, 4271-4282.
- Bi Rita, F., Fletcher, W. J., Aranbarri, J., Margaritelli, G., Lirer, F., Magri, D., 2018a. Holocene forest
   dynamics in central and western Mediterranean: periodicity, spatio-temporal patterns and
   climate influence. Scientific Reports 8, 8929.
- Di Rita, F., Molisso, F., Sacchi, M., 2018b. Late Holocene environmental dynamics, vegetation
   history, human impact, and climate change in the ancient *Literna Palus* (Lago Patria;
   Campania, Italy). Rev. Palaeobot. Palyno. 258, 48-61.
- Di Rita, F., Lirer, F., Bonomo, S., Cascella, A., Ferraro, L., Florindo, F., Insinga, D.D., Lurcock, P.C.,
  Margaritelli, G., Petrosino, P., Rettori, R., Vallefuoco, M., Magri, D., 2018c. Late Holocene
  forest dynamics in the Gulf of Gaeta (central Mediterranean) in relation to NAO variability
  and human impact. Quaternary Sci. Rev. 179, 137–152.
- Di Rita, F., Michelangeli, F., Celant, A., Magri, D., 2022. Sign-switching ecological changes in the
   Mediterranean Basin at 4.2 ka BP. Global Planet. Change 208, 103713.
- Fagel, N., Lechenault, M., Fontaine, N., Pleuger, E., Otten, J., Allan, M., Ghilardi, M., Mattielli, N.,
  Goiran, J-P., 2017. Record of human activities in the Pb isotopes signatures of coastal
  sediments from the Roman archaeological site of Cala Francese, Cape Corsica (France). J.
  Archaeol. Sci.: Reports 12, 770-781.
- Fletcher, W.J., Debret, M., Goñi, M.F.S., 2013. Mid-Holocene emergence of a low-frequency
  millennial oscillation in western Mediterranean climate: Implications for past dynamics of the
  North Atlantic atmospheric westerlies. The Holocene, 23, 153-166.
- Florenzano, A., Marignani, M., Rosati, L., Fascetti, S., Mercuri, A.M., 2015. Are Cichorieae an
  indicator of open habitats and pastoralism in current and past vegetation studies? Plant
  Biosyst. 149, 154-165.
- Franke, J.G., Werner, J.P., Donner, R.V., 2017. Reconstructing Late Holocene North Atlantic
   atmospheric circulation changes using functional paleoclimate networks. Clim. Past 13, 1593 1608.
- Galloway, J.M., Wigston, A., Patterson, R.T., Swindles, G.T., Reinhardt, E., Roe, H.M., 2013.
  Climate change and decadal to centennial-scale periodicities recorded in a late Holocene NE
  Pacific marine record: Examining the role of solar forcing. Palaeogeography,
  Palaeoclimatology, Palaeoecology 386, 669-689.
- Galop, D., Carozza, L., Marembert, F., Bal, M.C., 2007. Activités agropastorales et climat durant
  l'Âge du Bronze dans les Pyrénées : l'état de la question à la lumière des données
  environnementales et archéologiques, in: Mordant C., Richard H., Magny M. (Eds.),
  Environnements et cultures à l'âge du Bronze en Europe occidentale. Actes du 129e colloque
  du CTHS, Besançon, avril 2004, Editions du CTHS, Documents Préhistoriques, 21, 107-119.
- Gauthier, A., 2006. Des roches, des paysages et des hommes. Géologie de la Corse, Ajaccio, Edition
  Albiana, France, 276 p.
- Gelorini, V., Verbeken, A., van Geel, B., Cocquyt, C., Verschuren, D., 2011. Modern non-pollen
  palynomorphs from East African lake sediments. Rev. Palaeobot. Palyno. 164, 143-173.
- Ghilardi, M., 2020. Lagunes et marais littoraux de Corse. De la Préhistoire à nos jours. Collec. Orma:
   la Corse archéologie, Editions ARAC, 5, 105 p.
- Ghilardi, M., 2021. Geoarchaeology: Where Geosciences Meet the Humanities to Reconstruct Past
   Human–Environment Interactions. An Application to the Coastal Areas of the Largest
   Mediterranean Islands. Appl. Sci. 11, 4480. https://doi.org/10.3390/app11104480
- Ghilardi, M., Istria, D., Currás, A., Vacchi, M., Contreras, D., Vella, C., Dussouillez, P., Crest, Y.,
  Colleu, M., Guiter, F., Delanghe, D., 2017a. Reconstructing the landscape evolution and the

- human occupation of the Lower Sagone River (Western Corsica, France) from the Bronze
  Age to the Medieval period, in: Ghilardi M. and Lespez L. (Eds.), Geoarchaeology of the
  Mediterranean islands. J. Archaeol. Sci.: Reports, 12, 741-754.
- Ghilardi, M., Delanghe, D., Demory, F., Leandri, F., Pêche-Quilichini, K., Vacchi, M., Vella, M.A.,
  Rossi, V., Robresco, S., 2017b. Enregistrements d'événements extrêmes et évolution des
  paysages dans les basses vallées fluviales du Taravo et du Sagone (Corse occidentale, France)
  au cours de l'âge du Bronze moyen à final: une perspective géoarchéologique.
  Géomorphologie, Relief, Processus et Environnement 23, 15-35.
- Grimm, E.C., 1987. CONISS: a FORTRAN 77 program for stratigraphically constrained cluster
   analysis by the method of incremental sum of squares. Computers & Geosciences 13, 13-35.
- Hammer, Ø., Harper, D.A.T., Ryan, P.D., 2001. PAST: paleontological Statistics software package
   for education and data analysis. Palaeontol. Electron. 4, 9.
- Havinga, A.J., 1984. A 20-year experimental investigation into the differential corrosion
   susceptibility of pollen and spores in various soil types. Pollen Spores 26, 541–58.
- Henry, A.G. (Ed.), 2020. Handbook for the Analysis of Micro-particles in Archaeological Samples.
   Springer International Publishing.
- Isola, I., Zanchetta, G., Drysdale, R.N., Regattieri, E., Bini, M., Bajo, P., Hellstrom, J.C., Baneschi,
  I., Lionello, P., Woodhead, J., 2019. The 4.2 ka event in the Central Mediterranean: new data
  from a Corchia speleothem (Apuan Alps, Central Italy). Clim. Past 15, 135–151.
- Jalali, B., Sicre, M.-A., Kallel, N., Azuara, J., Combourieu-Nebout, N., Bassetti, M.-A., Klein, V.,
  2017. High-resolution Holocene climate and hydrological variability from two major
  Mediterranean deltas (Nile and Rhone). The Holocene 27 (8), 1158–1168.
- Jeanmonod, D., Schlüssel, A., 2006. Notes and contributions on Corsican flora, XXI. Candollea, 61,
  964 93-134.
- Jiménez-Moreno, G., Anderson, R.S., Ramos-Román, M.J., Camuera, J., Mesa-Fernández, J.M.,
  García-Alix, A., Jiménez-Espejo, F.J., Carrión, J.S., López-Avilés, A., 2020. The Holocene *Cedrus* pollen record from Sierra Nevada (S Spain), a proxy for climate change in N Africa.
  Quaternary Sci. Rev. 242, 106468.
- Kantrud, H.A., 1991. Wigeongrass (Ruppia maritima L.): A Literature Review, vol. 10. U.S. Fish and
   Wildlife Service, Fish and Wildlife Research, 58 pp.
- Kouli, K., Brinkhuis, H., Dale, B., 2001. *Spiniferites cruciformis*: a fresh water dinoflagellate cyst?.
  Rev. Palaeobot. Palynolo 113, 273-286.
- Lestienne, M., Jouffroy-Bapicot, I., Leyssenne, D., Sabatier, P., Debret, M., Albertini, P. J.,
  Colombaroli, D., Didier, J., Hély, C., Vannière, B., 2020a. Fires and human activities as key
  factors in the high diversity of Corsican vegetation. The Holocene 30, 244-257.
- Lestienne, M., Hely, C., Curt, T., Jouffroy-Bapicot, I., Vannière, B., 2020b. Combining the Monthly
  Drought Code and Paleoecological Data to Assess Holocene Climate Impact on
  Mediterranean Fire Regime. Fire 3(2), 8.
- Leleu, F., 2021. Calenzana–Les mines de l'Argentella. Prospection thématique (2018). ADLFI.
  Archéologie de la France Informations [Online], Corse, Online since 08 January 2021,
  connection on 14 December 2021. URL: http://journals.openedition.org/adlfi/50226
- Leys, B., Carcaillet, C., Dezileau, L., Ali, A.A., Bradshaw, R.H., 2013. A comparison of charcoal measurements for reconstruction of Mediterranean paleo-fire frequency in the mountains of Corsica. Quaternary Res. 79, 337-349.
- Leys, B., Finsinger, W., Carcaillet, C., 2014. Historical range of fire frequency is not the Achilles'
  heel of the Corsican black pine ecosystem. J. Ecol. 102, 381-395.
- Lugliè, C., 2018. *Your path led trough the sea*... the emergence of Neolithic in Sardinia and Corsica.
  Quatern. Int. 470, 285-300.
- Ma, L., Vaquero, J.M., 2020. New evidence of the Suess/de Vries cycle existing in historical naked eye observations of sunspots. Open Astronomy 29, 28-31.

- Magny, M., Joannin, S., Galop, D., Vannière, B., Haas, J. N., Bassetti, M., Bellintani, P., Scandolari,
   R., Desmet, M., 2012. Holocene palaeohydrological changes in the northern Mediterranean
   borderlands as reflected by the lake-level record of Lake Ledro, northeastern Italy. Quaternary
   Res., 77, 382–396.
- Magny, M., Combourieu-Nebout, N., de Beaulieu, J.L., Bout-Roumazeilles, V., Colombaroli, D.,
  Desprat, S., Francke, A., Joannin, S., Ortu, E., Peyron, O., Revel, M., Sadori, L., Siani, G.,
  Sicre, M.A., Samartin, S., Simonneau, A., Tinner, W., Vannière, B., Wagner, B., Zanchetta,
  G., Anselmetti, F., Brugiapaglia, E., Chapron, E., Debret, M., Desmet, M., Didier, J.,
  Essallami, L., Galop, D., Gilli, A., Haas, J.N., Kallel, N., Millet, L., Stock, A., Turon, J.L.,
  Wirth, S., 2013. North-south palaeohydrological contrasts in the central Mediterranean during
  the Holocene: tentative synthesis and working hypotheses. Clim. Past 9, 2043-2071.
- Magri, D., Di Rita, F., 2015. Archaeopalynological preparation techniques, in: Yeung, E.C.T.,
   Stasolla, C., Sumner, M.J., Huang, B.Q. (Eds.), Plant Microtechniques and Protocols. Springer
   International Publishing, Cham, pp. 495–506.
- Magri, D., Celant, A., Di Rita, F., 2019. The vanished Alnus-dominated forests along the Tyrrhenian
   coast. Catena 182, 104136.
- 1007Martín-Chivelet, J., Muñoz-García, M.B., Edwards, R.L., Turrero, M.J., Ortega, A.I., 2011. Land1008surface temperature changes in Northern Iberia since 4000 yr BP, based on  $\delta^{13}$ C of1009speleothems. Global Planet. Change 77, 1-12.
- Martìn-Puertas, C., Matthes, K., Brauer, A., Muscheler, R., Hansen, F., Petrick, C., Aldahan, A.,
  Possnert, G., van Geel, B., 2012. Regional atmospheric circulation shifts induced by a grand
  solar minimum. Nat. Geosci. 5, 397-401.
- Mattioni, C., Martin, M. A., Pollegioni, P., Cherubini, M., Villani, F., 2013. Microsatellite markers
   reveal a strong geographical structure in European populations of *Castanea sativa* (Fagaceae):
   evidence for multiple glacial refugia. Am. J. Bot. 100, 951-961.
- Médail, F., Monnet, A.-C., Pavon, D., Nikoli c, T., Dimopoulos, P., Bacchetta, G., Arroyo, J., Barina,
  Z., Albassatneh, M.C., Domina, G., Fady, B., Matevski, V., Mifsud, S., Leriche, A., 2019.
  What is a tree in the Mediterranean Basin hotspot? A critical analysis. Forest Ecosyst. 6, 17.
- Melis, R.T., Depalmas, A., Di Rita, F., Montis, F., Vacchi, M., 2017. Mid to late Holocene environmental changes along the coast of western Sardinia (Mediterranean Sea Global Planet. Change 155, 29-41.
- Melis, R.T., Di Rita, F., French, C., Marriner, N., Montis, F., Serreli, G., Sulas, F., Vacchi, M., 2018.
  8000 years of coastal changes on a western Mediterranean island: a multiproxy approach from the Posada plain of Sardinia. Mar. Geol. 403, 93-108.
- Michon, G., 2011. Revisiting the resilience of chestnut forests in Corsica: from social-ecological
   systems theory to political ecolog. Ecol. Soc. 16, 5.
- Moore, D.M., Reynolds, R.C. Jr., 1997. X-Ray diffraction and the identification and analysis of clay
   minerals. Oxford New York, Oxford Univ. Press, 378 pp.
- Pantaleón-Cano, J., Yll, E.I., Pérez-Obiol, R. Roure, J.M., 2003. Palynological evidence for
   vegetational history in semi-arid areas of the western Mediterranean (Almería, Spain). The
   Holocene 13, 109–19.
- Peche-Quilichini, K., 2011. Les monuments turriformes de l'Age du bronze en Corse: tentative de caractérisation spatiale et chronologique sur fond d'historiographie. In: Dominique Garcia (ed.) L'Age du bronze en Méditerranée. Recherches récentes, Errance, Paris, 155-170.
- Pedrotta, T., Gobet, E., Schwörer, C., Beffa, G., Butz, C., Henne, P.D., Morales-Molino, C., Pasta,
  S., van Leeuwen, J.F.N., Vogel, H., Zwimpfer, E., Anselmetti, F.S., Grosjean, M., Tinner, W.,
  2021. 8,000 years of climate, vegetation, fire and land-use dynamics in the thermomediterranean vegetation belt of northern Sardinia (Italy). Veget Hist Archaeobot. 30, 789813.
- Peyron, O., Combourieu-Nebout, N., Brayshaw, D., Goring, S., Andrieu-Ponel, V., Desprat, S.,
  Fletcher, W., Gambin, B., Ioakim, C., Joannin, S., Kotthoff, U., Kouli, K., Montade, V., Pross,

- 1042J., Sadori, L., Magny, M., 2017. Precipitation changes in the Mediterranean basin during the1043Holocene from terrestrial and marine pollen records: a model-data comparison. Clim. Past 13,1044249-265.
- Pichard, G., Arnaud-Fassetta, G., Moron, V., Roucaute, E., 2017. Hydro-climatology of the Lower
   Rhône Valley: historical flood reconstruction (AD 1300–2000) based on documentary and
   instrumental sources. Hydrolog. Sci. J. 62, 1772-1795.
- Poher, Y., Ponel, P., Médail, F., Andrieu-Ponel, V., Guiter, F., 2017. Holocene environmental history
  of a small Mediterranean island in response to sea-level changes, climate and human impact.
  Palaeogeogr. Palaeoecol. 465, 247-263.
- Pollegioni, P., Woeste, K., Chiocchini, F., Del Lungo, S., Ciolfi, M., Olimpieri, I., Tortolano, V.,
  Clark, J., Hemery, G.E., Mapelli, S., Malvolti, M.E., 2017. Rethinking the history of common
  walnut (*Juglans regia* L.) in Europe: its origins and human interactions. PLoS One 12,
  e0172541.
- Regattieri, E., Zanchetta, G., Drysdale, R.N., Isola, I., Hellstrom, J.C., Dallai, L., 2014. Lateglacial
   to holocene trace element record (Ba, Mg, Sr) from corchia cave (Apuan Alps, central Italy):
   paleoenvironmental implications. J. Quaternary Sci. 29, 381-392.
- Reille, M., 1975. Contribution pollen analytique à l'histoire tardiglaciaire et holocène de la végétation
   de la montagne corse. Thèse des sciences Aix-Marseille III.
- Reille, M., 1984. Origine de la végétation actuelle de la Corse sud-orientale; analyse pollinique de cinq marais côtiers. Pollen Spores 1 XXVI, 43-60.
- Reille, M., 1991. Les données de l'analyse pollinique. Rapport fouille programme Grotte du Norte di Tuda. Olmeta di Tuda, pp. 149-160.
- Reille, M., 1992a. New pollen-analytical researches in Corsica: the problem of Quercus ilex L. and
   Erica arborea L., the origin of Pinus halepensis Miller forests. New Phytol. 122, 359-378.
- 1066 Reille, M., 1992b. Pollen et spores d'Afrique du nord. Laboratoire de Bot. Hist. et Palynologie,
  1067 Marseille
- Reille, M.J., Gamisans, V., Andrieu-Ponel, V., De Balieu, J.-L., 1999. The Holocene at Lac de Creno,
   Corsica, France: a key site for the whole island. New Phytol. 141, 291-307.
- 1070 Reimer, P.J., Austin, W.E., Bard, E., Bayliss, A., Blackwell, P.G., Ramsey, C.B., Butzin, M., Cheng,
  1071 H., Edwards, R.L., Friedrich, M., Grootes, P.M., et al., 2020. The IntCal20 Northern
  1072 Hemisphere Radiocarbon Age Calibration Curve (0-55 cal kBP). Radiocarbon 62, 725-757.
- 1073 Revelles J., Ghilardi, M., Vacchi, M., Rossi, V., Currás, A., López-Bultò, O., Brkojewitsch, G., 2019.
   1074 Coastal landscape evolution of Corsica: palaeoenvironments, vegetation history and human
   1075 impacts since the Early Neolithic period. Quaternary Sci. Rev. 225, 105993.
- 1076 Revelles, J., Ghilardi, M., 2021. 49. Saint Florent (north Corsica, France). Grana 60, 158-160.
- Roberts, C. N., Woodbridge, J., Palmisano, A., Bevan, A., Fyfe, R., Shennan, S., 2019. Mediterranean
   landscape change during the Holocene: Synthesis, comparison and regional trends in
   population, land cover and climate. The Holocene, 29(5), 923-937.
- Rodwell, J.S. (ed.), 2000. British plant communities, vol. 5, Maritime communities and vegetation of
   open habitats. Cambridge: Cambridge University Press.
- Sabatier, P., Dezileau, L., Colin, C., Briqueu, L., Bouchette, F., Martinez, P., Siani, G., Raynal, O.,
   Von Grafenstein, U., 2012. 7000 years of paleostorm activity in the NW Mediterranean Sea
   in response to Holocene climate events. Quat. Res. 77, 1–11.
- Sabatier, P., Nicolle, M., Piot, C., Colin, C., Debret, M., Swingedouw, D., Perrette, Y., Bellingery,
  M.-C., Chazeau, B., Develle, A.-L., Leblanc, M., Skonieczny, C., Copard, Y., Reyss, J.-L.,
  Malet, E., Jouffroy-Bapicot, I., Kelner, M., Poulenard, J., Didier, J., Arnaud, F., Vannière, B.,
  2020. Past African dust inputs in the western Mediterranean area controlled by the complex
  interaction between the Intertropical Convergence Zone, the North Atlantic Oscillation, and
  total solar irradiance. Clim. Past 16, 283–298
- Schulz, M., Mudelsee, M., 2002. REDFIT: estimating red-noise spectra directly from unevenly
   spaced paleoclimatic time series. Computers & Geosciences 28, 421-426.

- Scott, L., 1992. Environmental implications and origin of microscopic *Pseudoschizaea* Thiergart and
   Frantz ex R Potonié emend. in sediments. J. Biogeogr. 19, 349-354.
- Szymczak, S., Joachimski, M. M., Bräuning, A., Hetzer, T., Kuhlemann, J., 2012. A 560 yr summer
   temperature reconstruction for the Western Mediterranean basin based on stable carbon
   isotopes from *Pinus nigra* ssp. *laricio* (Corsica/France). Clim. Past 8, 1737-1749.
- Sicurani, J., 2008. Étude technologique et typologique du matériel lithique taillé néolithique trouvé
  en place sur quelques sites majeurs du Nord-Ouest (Balagne) de la Corse. Thèse de Doctorat,
  Université de Corse, 714 p.
- Sicurani, J., Martinet, L., 2019. Teghja di Linu: un site de plein air du début du iiie millénaire av. J. C. (Luzzipeu, Haute-Corse). In Sicurani J. (dir.), L'habitat pré- et protohistorique/L'alloghju
   prestoricu è protostoricu, acte du Ier colloque de Calvi (Calvi, 28-30 avril 2017), ARPPC, 45 70.
- Stax, R., Stein, R., 1993. Long-term changes in the accumulation of organic carbon in Neogene sediments, Ontong Java Plateau, Proc. Ocean Drill. Program Sci. Results 130, 573-584.
- Stos-Gale, Z., Gale, N.H., Houghton, J., Speakman, R., 1995. Lead isotope data from the Isotrace
   Laboratory, Oxford: Archaeometry data base 1, ores from the Western Mediterranean.
   Archaeometry 37, 407–415.
- Terral, J.-F., Alonso, N., Buxó i Capdevila, R., Chatti, N., Fabre, L., Fiorentino, G., Marinval, P.,
  Pérez Jordá, G., Pradat, B., Rovira, N., Alibert, P., 2004: Historical biogeography of olive
  domestication (Olea europaea L.) as revealed by geometrical morphometry applied to
  biological and archaeological material. J. Biogeogr. 31, 63–77.
- Trouet, V., Esper, J., Graham, N.E., Baker, A., Scourse, J. D., Frank, D.C., 2009. Persistent positive
  North Atlantic Oscillation mode dominated the medieval climate anomaly. Science
  324(5923), 78-80.
- 1117 Vacchi, M., Ghilardi, M., Spada, G., Currás, A., Robresco, S., 2017. New insights into the sea-level
  evolution in Corsica (NW Mediterranean) since the late Neolithic. J. Archaeol. Sci.: Reports,
  119 12, 782-793.
- Vacchi, M., Joyse, K. M., Kopp, R. E., Marriner, N., Kaniewski, D., Rovere, A., 2021. Climate pacing
   of millennial sea-level change variability in the central and western Mediterranean. Nature
   communications 12(1), 1-9.
- Vacchi, M., Marriner, N., Morhange, C., Spada, G., Fontana, A., Rovere, A., 2016. Multiproxy
  assessment of Holocene relative sea-level changes in the western Mediterranean:sea-level
  variability and improvements in the definition of the isostatic signal. Earth Sci. Rev. 155, 1721126
- Vacchi, M., Ghilardi, M., Melis, R.T., Spada, G., Giaime, M., Marriner, N., Lorscheid, T., Morhange,
   C., Burjachs, F., Rovere, A., 2018. New relative sea-level insights into the isostatic history of
   the Western Mediterranean. Quat. Sci. Rev. 201, 396-408.
- van Geel, B., 2001. Non-pollen palynomorphs. In: Smol, J.P., Birks, H.J.B., Last, W.M. (Eds.),
   Tracking Environmental Change Using Lake Sediments. Terrestrial, Algal and Silicaceous
   Indicators, Volume 3. Kluwer, Dordrecht, pp. 99-119.
- 1133 Vecchio, A., Lepreti, F., Laurenza, M., Alberti, T., Carbone, V., 2017. Connection between solar
   1134 activity cycles and grand minima generation. Astronomy & Astrophysics 599, A58.
- 1135 Vella, M. A., Tomas, É., Thury-Bouvet, G., Muller, S., 2014. Nouvelles données sur le petit âge de 1136 glace en Corse: apports de l'analyse croisée des informations géomorphologique, 1137 palynologique et archéologique de la piève de Santo Pietro (désert de l'Agriate, Corse).
  1138 Méditerranée. Revue géographique des pays méditerranéens/Journal of Mediterranean 1139 geography, (122), 99-111.
- Vella, M.A., Andrieu-Ponel, V., Cesari, J., Leandri, F., Pêche-Quilichini, K., Reille, M., Poher, Y.,
  Demory, F., Delanghe, D., Ghilardi, M., Ottaviani-Spella, M.D., 2019. Early impact of agropastoral activities and climate on the littoral landscape of Corsica since mid-Holocene.
  PloS One, 14(12), e0226358.

- Vigne, J.D., 1984. Premières données sur les débuts de l'élevage du Mouton, de la Chèvre et du Porc
  dans le sud de la Corse (France), in: Clutton-Brock J. et Grigson C. (Eds.), Animals and
  Archaeology, 3 Early Herders and their Flocks. Proceedings 4th Int. Council for
  Archaeozoology, Londres, 1982, Oxford, Archaeopress, BAR International Series, 202, 4765.
- 1149 Vigne, J.D., 1987. L'exploitation des ressources alimentaires en Corse du VIIe au IVe millénaire. In
  1150 : Guilaine, J., Courtin, J., Roudil, J.L. et al. (Eds.), Premières communautés paysannes en
  1151 Méditerranée occidentale. CNRS éditions, 193-199.
- Weis, D., Kieffer, B., Maerschalk, C., Barling, J., de Jong, J., Williams, G.A., Hanano, D., Pretorius,
  W., Mattielli, N., Scoates, J.S., Goolaerts, A., Friedman, R.M., Mahoney, J.B., 2006. Highprecision isotopic characterization of USGS reference materials by TIMS and MC-ICP-MS.
  Geochem. Geophys. Geosyst. 7, Q08006.
- Weiss, M.-C., 2010. Au VIe millénaire avant notre ère. A Petra à L'île Rousse : campagnes de fouilles
   (2003-2006), Ajaccio, Albiana, 247 p.
- Wu, J., Yu, Z., Zeng, Z., Wang, N., 2009. Possible solar forcing of 400-year wet–dryclimate cycles
   in northwestern China. Climatic Change 96, 473-482.
- Yu, Z.C., Ito, E., 2002. The 400-year wet–dry climate cycle in Interior North America and its solar
   connection. In: West, G.J., Blomquist, N.L. (Eds.), Proceedings of the nineteenth annual
   pacific climate workshop. Technical Report 71, 159–163.
- Zanchetta, G., Regattieri, E., Isola, I., Drysdale, R., Bini, M., Baneschi, I., Hellstrom, J., 2016. The
  so-called "4.2 event" in the central Mediterranean and its climatic teleconnections. Alp.
  Mediterr. Quat. 29, 5-17.
- Zonneveld, K.A.F., Marret, F., Versteegh, G.J.M., Bonnet, S., Bouimetarhan, I., Crouch, E., de 1166 Vernal, A., Elshanawany, R., Edwards, L., Esper, O., Forke, S., Grøsfjeld, K., Henry, M., 1167 1168 Holzwarth, U., Kielt, J.-F., Kim, S.-Y., Ladouceur, S., Ledu, D., Chen, L., Limoges, A., Londeix, L., Lu, S.-H., Mahmoud, M.S., Marino, G., Matsouka, K., Matthiessen, J., 1169 Mildenhal, D.C., Mudie, P., Neil, H.L., Pospelova, V., Qi, Y., Radi, T., Richerol, T., Rochon, 1170 1171 A., Sangiorgi, F., Solignac, S., Turon, J.-L., Verleye, T., Wang, Y., Wang, Z., Young, M., 1172 2013. Atlas of modern dinoflagellate cyst distribution based on 2405 datapoints. Rev. 1173 Palaeobot. Palynol. 191, 1-197.
- 1174 1175

LablID	Material	Depth (cm)	<sup>14</sup> C Age±error BP	Cal. yr BP (2σ)	Cal. yr AD/BC (2σ)
GdA-5806	Organic sediment	49	1585±25	1527-1404	423-546 AD
Poz-115796	Organic sediment	50	3090±40	3389-3179	1440-1230 BC
GdA-5807	Organic sediment	77	2215±30	2330-2146	381-197 BC
GdA-5808	Organic sediment	93	2280±25	2349-2177	400-209 BC
Poz-110261	Charcoal	125	3260±90	3699-3252	1750-1301 BC
GdA-5809	Organic sediment	138	3090±35	3382-3210	1433-1261 BC
GdA-5810	Organic sediment	154	3215±30	3480-3373	1531-1424 BC
Poz-110260	Plant + Peat	185	3420±35	3823-3569	1874-1620 BC
GdA-5811	Organic sediment	229	4170±40	4834-4577	2885-2628 BC
Poz-110258	Peat	270	4175±35	4835-4580	2886-2631 BC
Poz-109794	Charcoal	340	4470±40	5297-4967	3348-3018 BC
Poz-110198	Peat	397	4530±30	5312-5051	3363-3102 BC
Poz-109887	Charcoal	450	4730±40	5581-5325	3632-3376 BC
Poz-105992	Bulk Sediment	487	5080±40	5917-5730	3968-3781 BC

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1177 Table 1. AMS Radiocarbon ages obtained from the materials of Crovani core. The calibrated ages

1178 are based on Intcal20 dataset (Reimer et al., 2020).

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# 1180 Figure Captions

- 1181 Figure 1. Location map of the study area and coastal sites of previous palynological research (white
- 1182 circle) conducted over the last decade for Corsica island (Del Sale: Currás et al., 2017; Sagone:
- 1183 Ghilardi et al., 2017a; Palo, Piantarella and Saint-Florent: Revelles et al., 2019, Revelles and
- 1184 Ghilardi, 2021; Canniccia: Vella et al., 2019). The purple squares indicate the position of known
- 1185 mining sites of galena/lead in Corsica. A: Hydrography and archaeology of the catchment basins
- ending in the Crovani Bay, green circle: Final Neolithic to Bronze Age site; Red circle: possible
- 1187 roman site of occupation; Orange square: 19<sup>th</sup> to 20<sup>th</sup> Cent. AD mining buildings; light green stars:
- 1188 Medieval site; 1: San Larenzu, 2: San Quilicu, 3: Teghja di Linu, 4: lower Argentella, 5: upper
- Argentella. B: Simpilified geology and topography of the catchment basins ending in the Crovani
  Bay; Orange square: mining site Geographic coordinates are expressed in WGS 84 geodetic system.
- 1191
- Figure 2. View of the Crovani pond, borehole and Differential Global Positioning System- DGPSprofile (AA') locations. The light blue line (dash) indicates the present-day course of the rivers.
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Figure 3. Age-Depth Model of the Crovani sequence, calculated through a Bayesian method using
the computer program Bacon 2.5.5 (Blaauw and Christen, 2011). The Model is based on 14 AMS
dates calibrated using the IntCal20 curve (Reimer et al., 2020).

Figure 4. Core lithology with ages expressed in cal. BC/AD and depths indicated in cm (left). For full
details of the samples performed for <sup>14</sup>C AMS dating method (red squares), please check Table 1.
Curves from left to right: Loss on ignition measurements with organic matter and carbonate contents,
granulometric indexes (mean and mode), mineralogical and geochemical proxies (halite, C/N ratio)
and Arboreal Pollen (AP) concentration (grains/gram).

Figure 5. A: Pb isotope results of the Crovani sedimentary core LCr18 reported in a binary diagram 1205 <sup>207</sup>Pb/<sup>206</sup>Pb versus <sup>208</sup>Pb/<sup>206</sup>Pb. The dashed line indicates the linear regression trend between the 1206 Crovani samples. Circles: Crovani samples reported by different colors according to their 1207 1208 stratigraphical position, i.e. pre-Roman samples, Roman and modern samples. The black circle 1209 indicates the average signature of the local geological background defined by the oldest measured 1210 Final Neolithic samples. Black symbols: samples from different Pb-bearing mineral collected in West 1211 Corsica. The red triangle gives the averaged composition of modern airborne particles collected above Roma in Italy (data from Bollhöfer and Rosman, 2001). Green squares: signature of Pb galene-rich 1212 ores from Sardinia. B: Close up emphasizing the representative signature of Pb ore mining districts 1213 1214 surrounding the Mediterranean basin classed by country (green for Italy, blue for Greece, purple for 1215 Turkey and various colors from grey to orange for Spain ores). Data from literature reported in Fagel 1216 et al., (2017). The black arrow represents an extrapolation of the sedimentary mixing observed in core 1217 LCr18 in Figure 5A. It underlines the probable implication of the minerals of Tuscany in the Pb 1218 isotope signature of the Crovani sediments.

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Figure 6. Pollen percentage diagram of Crovani, including the pollen zonation calculated with the
CONISS method (Grimm, 1987).

1223 Figure 7. Percentage diagram of Non-Pollen Palynomorphs from Crovani.

Figure 8. Summary pollen diagram including the cumulative percentages of gymnosperms, riparian
trees, deciduous trees, evergreen trees and shrubs, OJCV curve, anthropogenic herbs, other herbs,
coprophilous fungi, and saproxylic and phytopathogenic fungi, the Arboreal Pollen percentage
record, the concentrations of Arboreal Pollen and Non-Arboreal Pollen, and the microcharcoal
concentrations. The light green bars indicate phases of high storm activity in southern France

(Sabatier et al., 2012). The blue bars indicate lake level highstands at Lake Accesa in central Italy
(Magny et al., 2013). The orange bars indicate phases of dry climate conditions in south-central
Mediterranean (Di Rita et al., 2018a). The NAO index is based on Franke et al. (2017).

Figure 9. REDFIT (A) analysis of the total Arboreal Pollen percentages (B) using the PAST 3.2 software program (Hammer et al., 2001). In the REDFIT spectral analysis the time series is fitted to an AR1 red noise model (orange line). The 95% confidence levels of the  $\chi^2$  and Monte Carlo tests are reported on the graph with a green dashed line and a red dashed line, respectively.

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Figure 10. Synoptic table with timing and nature of key environmental changes reconstructed fromthe Crovani record.

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BP 0	Cm	Litho.	Lacustrine environment	Vegetation evolution	Human impact	Vegetation	RCC	Fire activity	Cultural phases	BC/AD
0	0		Soil erosion and downwash	Recovery of Erica and Q. Ilex maguis	'Chestnut civilization' and Olea exploitation	Incresed natural &cultivated trees	Little Low	Low High	Modern Genoese	
1000			of Pseudoschizaea and Glomus	Open vegetation with Cistus formations	Human influence on vegetation opening and soil erosion	Forest decline	Medieval Anomaly		Middle	E-1000
				Decline of Q. ilex	Increase in maquis degradation	1	Homeric		Ages	Ē
2000			Freshwater pond rich in pteridophytes	of Erica maquis	Olea exploitation in lowlands. Galena exploitation Poor farming activity	General forest			Roman	E.
		with Alnus and sedges	with Alnus and sedges	Q. ilex-dominated woodlands					2010/01/201	Ē
	100			Decline of Erica	Early stage of human-induced				Age	
3000			Complex dynamics	of Q. ilex woodlands	maquis degradation	Deep vegetation rearrangement	3.2 ka drv event		r A late	1000
	150		related to increased runoif	<i>Erica-</i> dominated tall maquis with <i>Q. ilex</i> and other evergreen elements	cereal cultivation, sporadic pastoral activity				n e middle	E
4000	200		Brackish swamp with <i>Ruppia</i> , surrounded by sedges and reeds			Dense maquis 4. and er Fagus increase	4.2 ka event		e early	E 2000
	250				Livestock rearing and decline of cereals cultivation				Final Neolithic	Ē
	-300									Eanon
5000-	1350		Swamp with phytoplankton		Cereals cultivation and livestock rearing activities				Late	E
	450		dominated by Spiniferites as early stage of an						Neolithic	E
6000	500		hydrosere succession					5		<u></u> _4000

## **Declaration of interests**

 $\boxtimes$  The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

□The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

## Authors' Contributions

All authors have materially participated in the research project and article preparation, as follows. Conceptualization: FDR, MG, NF, and MV. Sediment collection: MG, JS and LM. Methodology: FDR, MG, NF, and MV. Formal analyses: FDR, MG, NF, MV, FW, DD, and SR. Data collection: FDR, MG, NF, MV, FW, DD, JS, LM, and SR. Results interpretation: FDR, MG, NF, and MV. Writing original draft: FDR, MG, NF, and MV. Contribution in interpreting results and writing the paper: FW, DD, JS, LM, and SR. Funding acquisition: MG. Supplementary Data

Click here to access/download **e-Component/Supplementary data** Di Rita et al\_Supplementary material\_rev\_2.docx