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Human–climate interactions in the central Mediterranean region during the last millennia: The laminated record of Lake Butrint (Albania)

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ABSTRACT

Lake Butrint (39°47 N, 20°1 E) is a ca. 21 m deep, coastal lagoon located in SW Albania where finely-laminated sediments have been continuously deposited during the last millennia. The multi-proxy analysis (sedimentology, high-resolution elemental geochemistry and pollen) of a 12 m long sediment core, supported by seven AMS radiocarbon dates and ^{137}Cs dating, enable a precise reconstruction of the environmental change that occurred in the central Mediterranean region during the last ~4.5 cal kyrs BP. Sediments consist of triplets of authigenic carbonates, organic matter and clayey laminae. Fluctuations in the thickness and/or presence of these different types of seasonal laminae indicate variations in water salinity, organic productivity and runoff in the lake's catchment, as a result of the complex interplay of tectonics, anthropogenic forcing and climate variability. The progradation of the Pavllo river delta, favoured by variable human activity from the nearby ancient city of Butrint, led to the progressive isolation of this hydrological system from the Ionian Sea. The system evolved from an open bay to a restricted lagoon, which is consistent with archaeological data. An abrupt increase in mass-wasting activity between 1515 and 1450 BC, likely caused by nearby seismic activity, led to the accumulation of 24 homogenites, up to 17 cm thick. They have been deposited during the onset of finely laminated sedimentation, which indicates restricted, anoxic bottom water conditions and higher salinity. Periods of maximum water salinity, biological productivity, and carbonate precipitation coincide with warmer intervals, such as the early Roman Warm Period (RWP) (500 BC–0 AD), the Medieval Climate Anomaly (MCA) (800–1400 AD) and recent times (after 1800 AD). Conversely, lower salinity and more oxic conditions, with higher clastic input were recorded during 1400–500 BC, the Late Roman and the Early Medieval periods (0–800 AD) and during the Little Ice Age (1400–1800 AD). Hydrological fluctuations recorded in Butrint are in phase with most central and western Mediterranean records and correlate with NAO variability. In contrast, opposite hydrological patterns have been recorded in the Eastern Balkans and the Levant during the last millennium, emphasizing a complex spatial variability in the region. Phases of maximum settlement intensity in Butrint (Roman-Late Antique) coincide with warmer and/or stable climate periods (0–800 AD and MCA, respectively), indicating a long-term influence of climatic conditions on human activities. The Late Holocene sedimentary record of Lake Butrint demonstrates the complex interplay of climate variability, tectonics and human impact in the recent evolution of coastal Mediterranean regions.

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1. Introduction

During its long history of human occupation, the Mediterranean Basin has experienced significant climate fluctuations with a particularly intense impact in the hydrological cycle (Fletcher and Zielhofer, 2013; Luterbacher et al., 2005). Thus, this region stands out as ideally suited to study the complex interactions between climate variability and human activities during the last millennia (Lavorel et al., 1998; Manning, 2013; McCormick et al., 2012; Roberts et al., 2004), representing the two main factors to drive landscape evolution during the late Holocene (Anthony et al., 2014; Grove and Rackham, 2003).

The Mediterranean coastal areas have been densely populated since prehistoric times, provided essential resources and acted as a natural communication link between the major cultural centres (Marriner et al., 2014). These areas are subjected to an increasing human pressure due to population growth and rising demand for marine resources (UNEP/MAP, 2012) and are threatened by sea level rise in the context of Global Change (Giorgi and Lionello, 2008). Thus, a more detailed knowledge of how climate and ecosystems – including human societies – interacted in the past during phases of environmental change is essential to develop sound adaptation and mitigation policies in these areas.

Sea level rise affected the Mediterranean coastal lowlands by the Holocene marine transgression and led to the formation of inlets, embayments and lagoons (Avramidis et al., 2013). Sediments deposited in these coastal lagoons provide archives of Holocene environmental change, driven by a complex interplay of climate variability, sea level fluctuations, occasional seismic activity (Vött, 2007; Vött et al., 2009) and human impact (Devillers et al., 2015; Koutsodendris et al., 2015). However, investigated coastal sites in the central and Eastern Mediterranean region are relatively scarce (e.g., Lake Shkodra, Albania (Zanchetta et al., 2012); Amvrakikos Lagoon, Greece (Avramidis et al., 2014); Patria Lagoon, Italy (Sacchi et al., 2014); Larnaca salt lake, Cyprus (Kaniewski et al., 2013) and Syrian coastal plains (Kaniewski et al., 2008) among others (Di Rita and Magri, 2012)) and, if we exclude ancient ports (Marriner and Morhange, 2007; Sadori et al., 2015a), most of the paleoenvironmental information comes from marine cores far offshore and from continental records recovered at highland areas, often subjected to moister and/or colder conditions (Roberts et al., 2008).

Marine records from the Mediterranean region have widely documented the impact of intra-Holocene high-frequency climate variability (Desprat et al., 2013; Rohling et al., 2002). Temperature fluctuations that occurred during the last 2 ka, responding to traditionally identified intervals such as the Medieval Climatic Anomaly (MCA) (950–1350 AD) and the Little Ice Age (LIA) (1500–1850 AD), with global temperatures above or below average, respectively (Mann and Jones, 2003; Osborn and Briffa, 2006). Continental sequences from the Balkans (e.g., lakes Ohrid (Lacey et al., 2014), Prespa (Leng et al., 2013), Dojran (Zhang et al., 2014)), Anatolia (Fleitmann et al., 2009; Jones et al., 2006; Woodbridge and Roberts, 2011) and the Levant (Bar-Matthews et al., 2003; Migowski et al., 2006a) have recorded a consistent millennial-scale response to a Late Holocene aridification trend within a framework of variable human impact. However, contrasting hydrological patterns have been found locally within this region at shorter timescales during the last millennium (Roberts et al., 2012). Thus, more records from coastal regions are needed to understand Late Holocene environmental changes that occurred in response to climate variability and human impact.

In this study, we investigate a continuous, laminated and high-resolution sedimentary sequence recording environmental change that occurred in the central Mediterranean region during the last ~4.5 cal kyrs BP. We performed a multi-proxy analysis of sediment cores recovered from Lake Butrint (Albania) comprising sedimentologic studies, high-resolution elemental geochemistry, pollen and biogenic silica. Previous studies (Ariztegui et al., 2010) demonstrated the potential of this sequence as an archive of climate variability, human impact and tectonic activity in the region for the last 300 years. The outstanding archaeological sequence of the ancient city of Butrint, located on a peninsula surrounded by the lake waters and continuously occupied since the 6th century BC by Greeks, Romans, Byzantines, Venetians and Ottomans, offers a unique opportunity to discuss the complex interactions between landscape changes and human activities. The paleoenvironmental record of Lake Butrint shows the long-term influence in the sedimentary budget of the lake of geomorphological changes in the catchment that have been modulated by both tectonics and human impact. Along with the short-term impact of climate variability, they are the main drivers of environmental change in Mediterranean coastal areas. The multidisciplinary approach used in this research, together with the finely laminated nature of the sequence, allows a precise identification of the main sediment components associated with different sources and forcing mechanisms, which serve as the agents for environmental reconstructions. Furthermore, the correlation of the reconstructed hydrological fluctuations with other records from the Western and Eastern Mediterranean region suggests a large spatial variability and climatic teleconnections during certain key intervals.

2. Regional setting

2.1. Geographical and geological setting

Lake Butrint (39°47 N, 20°1 E) is the southernmost lagoon of the Albanian coast of the Ionian Sea (Fig. 1A), ~5 km north of the Greek Border. It is surrounded by the Vurgu Plain to the north, the Mile Mountains to the east, the Vrina Plain to the south and the Ksamili Peninsula to the west (Tsabaris et al., 2007) (Fig. 1B). The lake basin occupies a N–S extending graben structure formed during the Pleistocene, which has experienced subsidence until recent times and was invaded by Mediterranean Sea water during the Holocene transgression (Aliaj et al., 2001; Meco and Aliaj, 2000). This subsidence led to submerged archaeological Roman and post-Roman remains occurring today below the current water table in the nearby archaeological site of Buthrotum (Lane, 2004).

The bedrock of the lake basin is composed of: i) mid Jurassic to mid Cretaceous limestones, outcropping at the Ksamili Peninsula and the southern part of the Milë Mountain and ii) Paleocene flysch at the northeastern areas of the lagoon (Tsabaris et al., 2007). Butrint is located near the European plate–Adriatic microplate boundary, in one of the most tectonically active regions of the Mediterranean Basin (Meco and Aliaj, 2000; Muço, 1995). Ariztegui et al. (2010) have previously interpreted homogeneous layers within a laminated sequence covering the last ~300 years as earthquake-induced mass-wasting events, coinciding with the historically reported events of 1794, 1811, 1872 and 1917 AD.

2.2. Climate and vegetation

Climate conditions in the region are of Mediterranean type, with a relatively high total annual rainfall ~1500 mm per year, mostly occurring between November and March, and a dry summer season. Mean monthly temperatures range from 9.7 °C in January to 25.1 °C in August. Southern winds dominate during winter and fall whereas Northern winds prevail during spring and summer (Lane, 2004). Similarly to other areas of the central and eastern Mediterranean Basin, long-term rainfall variability is mostly related to the North Atlantic Oscillation (NAO) and the Eastern Atlantic pattern