Title

A long hard road... Reviewing the evidence for environmental change and population history in the eastern Adriatic and western Balkans during the Late Pleistocene and Early Holocene

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Abstract

The eastern Adriatic and western Balkans are key areas for assessing the environmental and population history of Europe during the Late Pleistocene and early Holocene. It has been argued that the Balkan region served as a Late Glacial refugium for humans, animals, and plants, much like Iberia and the Italian Peninsula and in contrast to the harsh conditions of Eastern and Central Europe. As post-glacial amelioration occurred and sea level rose, these regions to the north and west of the Balkan Mountains became forested and were populated by Mesolithic forager-fishers. Meanwhile, to the south, the domestication of plants and animals in the Near East began to cause large-scale environmental as well as lifestyle changes. Even as the Balkan Peninsula was a likely crossroads on the route for the spread of agriculture and herding from Southwest Asia into Europe, issues such as pre-Neolithic settlement, the discussion of human-environment interactions, and the role of climate events such as the 11.4, 9.3, and 8.2 ka cal BP in this critical landscape are often overlooked. Efforts to counter this challenge have been hampered by an apparent lack of data, so that the region hardly occurs in distribution maps. In part this is due to patchy research and a complicated political history, which have contributed to a fragmented archaeological and paleoecological record. Yet, as we show here, there is in fact plenty of evidence available for review. We present a survey of different proxies for environment and settlement throughout the Late Pleistocene and into the Early Holocene, combining radiocarbon data with zooarchaeological, lithic, and palynological records. By mapping this evidence, we are able to discuss the impact of climate change during the Pleistocene/Holocene transition and consider the role of environment and landscape on human population distribution at this crossroads in place and time.

Keywords

Pleistocene/Holocene transition, population history, radiocarbon dating, environmental change, Mesolithic, Late Upper Paleolithic

1. Introduction

The Pleistocene-Holocene transition in the eastern Adriatic was a time of drastic environmental change. Noticeable landscape transformations occurred within individual lifetimes and on a generational basis during the Late Upper Paleolithic (late Pleistocene) and Mesolithic (early Holocene). However, links between environment and settlement remain difficult to ascertain. In this paper, we consider how climate change and the inundation of the Great Adriatic Plain affected regional landscapes and establish an environmental context for changing settlement patterns and the distribution of human populations from approximately 15,000-8,000 years ago—the end of the last ice age to the arrival of agricultural lifestyles in the region. We first present a review of paleoenvironmental evidence for the late Pleistocene and early Holocene and describe the nature of sea level rise before discussing the archaeology of the wider region.

In the Pleistocene, the Great Adriatic Plain was a large expanse of flat lowland. Climate change and sea level rise during the postglacial caused considerable changes in environment, vegetation, topography, and ecology. The Great Adriatic Plain is now covered by the northern third of the present-day Adriatic Sea. It has been argued both that the Great Adriatic Plain would have been rich in game, water, and lithic resources (Bailey and Gamble, 1990, Miracle, 1995, 2007, van Andel, 1989) and that it was a barren, saline wasteland (Mussi, 2001) during the Pleistocene. In the Holocene, the inundation of the Plain would have had significant implications for Mesolithic forager populations as they had to move inland and potentially intensify their use of upland cave sites and hinterland open air sites.

1.1. **The Environmental Basis of Mobility and Settlement**

Kvamme and Jochim (1989) suggested four environmental factors governing Mesolithic site choice and use that can be applied more broadly here to pre-agricultural settlement: landform, including relief, elevation, and slope; water availability, both horizontal and vertical distance to water, and separately, those distances to large "permanent" water sources; view, including that of animals and enemy/friendly human groups; and finally, shelter, including the aspect of the site (N-S, E-W) and exposure. In addition, *seasonal* regional animal and plant resource availability and abundance should also be considered (e.g. Pilaar Birch, 2012). This seasonal availability would determine when to use which site within the wider regional settlement system. Finally, in order to clarify the relationship between environmental determinants and economic choices, the application of the criteria by which we place animals in the landscape and wider region must be consistent, and proportional representations of animal habitats and relative distances from sites must be considered in comparison with their likelihood of representativeness (Sturdy et al., 1997).

In the Balkans, the vegetation during the Pleistocene was composed of periglacial tundra, steppe, and boreal forest, as well as refugial populations of broad-leaved deciduous taxa (Rossignol-Strick et al., 1992, Willis, 1994, Médail and Diadema, 2009). Even at the Last Glacial Maximum (hereafter LGM), the southern extent of permafrost reached no further than 45° latitude (Bailey, 2000). The Adriatic was a large coastal plain (van Andel and Shackleton, 1982) and sea level was approximately 130m below present day (Lambeck et al., 2002, 2004). The four main ungulate species exploited in the Paleolithic throughout temperate Europe were red deer, horse, aurochs/bison, and reindeer, which occur in large numbers, high density, have a large body size and high reproduction rates, and are known to migrate on a seasonal basis in some cases (Britton et al., 2011, Gamble, 1986, Pellegrini et al., 2008, Pilaar Birch et al., 2016). These were followed in relative abundance by roe deer, chamois/ibex, elk, and to a lesser extent, musk ox (Gamble, 1986). These species have either higher rates of reproduction or smaller migratory ranges, which would have made them more predictable (Gamble, 1986). Access to these resources may have been crucial in site selection within the landscape. It is generally agreed for the Late Upper Paleolithic in the Mediterranean and Europe that forager groups were highly mobile (Pluciennik, 2008) with reuse of sites on a single-season basis depending on availability of migrating species. However, postglacial environmental change would have created a widespread shift in resource exploitation throughout the Balkans and indeed, all of Europe (Bailey, 1992, Bailey et al., 1983). Mobility patterns would have changed as new upland areas came into use, and in some cases there was a broadening of the resource base. There is a high degree of regional variability as to what constitutes Mesolithic subsistence strategies and material culture throughout the wider Mediterranean region and Europe (Pluciennik, 2008, Spikins, 2008).

In addition to the apparent diversity of Mesolithic archaeology throughout Europe, a number of scenarios have been proposed which attempt to provide frameworks for understanding large-scale changes in mobility and subsistence with reference to their environmental settings at the Pleistocene-Holocene transition in different geographic regions. For example, though Dolukhanov (2008) provided summaries of smaller scale settlement and subsistence patterns in Eastern Europe divided into four environmental categories (the "mountainous fringe" of the Crimea and Carpathians, the steppe, mixed forests, and boreal forests), he suggested in general that large-scale migration of human groups took place in response to late glacial environmental changes in the East European Plain. This occurred as groups who had been hunting big game such as mammoths and bison during the LGM would have settled along riverine and lacustrine environments at the end of the Pleistocene, which allowed them to pursue seasonally migrating ungulates such as reindeer. He proposed that the expansion of forests in the early Holocene led to changes in subsistence, such as the exploitation of forest-steppe taxa (red and roe deer and wild boar), rather than any further large-scale population movements. In early Holocene Italy, Pluciennik (1995) described a regional settlement pattern in which sites were first located within 10km of the coast and gradually moved higher and further inland through time. This was accompanied by an increase in birds, fish and shellfish in addition to red deer and boar at the Pleistocene-Holocene boundary and an increase in ibex and chamois at the higher elevation sites later in time. In Greece, Runnels (1995) suggested depopulation between the Paleolithic and Mesolithic based on widespread gaps and discontinuities in the archaeology, which he attributed to low population densities and the loss of steppe and open forest habitats at the end of the Pleistocene. He proposed that Mesolithic population size was small and consisted mainly of colonisers from southwest Asia who inhabited coastal areas and focused on marine resources in addition to red deer and wild boar.

While larger scale population movements during the late glacial might appear to be a common thread, there is no clear trend in smaller scale changes in mobility patterns or subsistence during the Pleistocene-Holocene transition in the Mediterranean and whole of Europe since these are likely due to very specific local environmental factors (cf. Pluciennik, 2008, Spikins, 2008). It is therefore instructive to take a closer look at the archaeology within its environmental context in order to draw conclusions and avoid generalities about the nature of Late Upper Paleolithic and Mesolithic mobility and settlement patterns.

2. Regional Setting: Climate, Environment, and Sea Level Rise

The most important influencing climate factors on the eastern portion of the Balkan Peninsula include its position in the northern mid-latitudes, the Adriatic Sea, and the altitude of the Dinaric Alps. The modern climate of the interior is temperate, but on the islands and along the coast, the climate reaches subtropical conditions due to southerly weather patterns, with gentle winds across the sea in the northern Adriatic. There are greater local differences in weather during colder parts of the year when a strong northern wind (bora) blows at high speeds across the sea and weakens as it moves further from shore. Topographic variation strongly influences vegetative ground cover. This varies from wooded mountains and grassy plains in central Istria to karstic landscapes in the Dinarides. The North Atlantic Oscillation (NAO) is intimately linked with the climate of Greenland and northern Europe, but has also been shown to affect both European and Mediterranean climate as far back as the LGM (Chondrogianni et al., 2004). Prevailing westerlies push mild air across Europe and pull cold air into the eastern Mediterranean to cause colder, wetter winters. Strong westerlies will result in warmer winters in northern Europe, colder ones in the Near East, and increased rainfall in Eastern Europe (Chondrogianni et al., 2004).

Ice cores from Greenland provide a general climate record for the North Atlantic (Dansgaard et al., 1993, Johnsen et al., 1992, Blockley et al., 2012, Lowe et al., 2008, Rasmussen et al., 2014), but multiple proxies from the study region must be consulted in order to identify the presence and effects of global climate events on a regional and local scale. Local paleoclimate proxies include tree rings, oxygen isotopes, pollen and microfossils from marine and lake cores, and speleothem growth. Oxygen isotopes from marine shell and ungulate teeth may also provide useful, archaeologically-tied seasonal climate proxies. Though all of these can be influenced by more than one meteorological factor, a combination of multiple proxies allows for more robust interpretations that are comparable across geographic regions. The nature of water circulation is important to consider when interpreting paleoenvironmental proxies from Adriatic sediment cores, especially pollen. Much of the freshwater input into the Adriatic from the east coast is via the subterranean flow of water through carbonate rocks (Poulain and Raicich, 2001), but its overall contribution remains minimal when compared to the input of the Pô river (Combourieu-Nebout et al., 2013). Cores from this region are considered useful for reconstructing regional environment because the northern Adriatic behaves as an open sea during fall and winter, with less movement of water occurring during spring and summer, during most pollen production (Artegiani et al., 1997).

Dates for climate periods and their environmental effects are often variable, depending on the region as well as type of proxy and dating method used. Dates used here follow the paleoclimatic periods described within Blockley and colleagues (2012) and Rasmussen and colleagues (2014). Although all dates are reported in the original publications using the b2k convention, we have here converted them to cal BP in order to enable direct comparison with archaeological data. The date for the Pleistocene-Holocene transition is recognized at approximately 11,650 cal BP as set by the International Union of Geological sciences (Walker et al., 2009).

Sea level rise and isostatic uplift occurred worldwide at the end of the last glaciation. In addition to abrupt climate events, sea level rise presents a punctuated gradual trend over a long period of time, reducing habitat size and decreasing terrestrial resource abundance. Cooling events would have slowed or halted sea level rise intermittently in some areas. This has implications for the changing character of past coastal environments as both barriers and pathways for seasonal mobility and long-distance migration and settlement. The geographical and environmental effects of global sea level rise depended on local terrain (especially slope) and elevation. The nature of sea level rise is most often estimated through models, but speleothem growth and coastal margin sediment cores are most useful for reconstructing local sea level incursion (i.e., Stefani and Vicenzi, 2005, Surić et al., 2005). Sea level rise had a particularly dramatic impact on the region's topography and environment because the northern Adriatic is extremely shallow; the southern portion of the sea accounts for 80% of its total volume (Zore-Armanda, 1983).

3. Paleoenvironmental and Archaeological Data: Materials and Methods

This paper reviews the known paleoenvironmental and archaeological data for the period covering the Terminal Pleistocene and Early Holocene in the western Balkans, with a particular focus on the modern geographic entities of Slovenia, Croatia, Bosnia and Herzegovina, Serbia, and Montenegro. It must be pointed out that this research area overall presents a relatively low density of both paleoenvironmental and archaeological data, especially when compared to neighbouring regions (cf. maps in Feurdean et al., 2014, Mauri et al., 2015). For instance, terrestrial palynological archives covering either the Pleistocene / Holocene transition or the early Holocene are scarce, and include Lake Bled in Slovenia (Andrič et al., 2009), Lake Vrana on the island of Cres, Croatia (Schmidt et al., 2000) and Lakes Maliq, Prespa and Ohrid at the Albanian-Macedonian-Greek border (e.g. Denèfle et al., 2000, Leng et al., 2010, Aufgebauer et al., 2012, Bordon et al., 2009). Marine records, which present a much coarser temporal and spatial resolution, include cores from the northern extent of the Adriatic (e.g., Favero and Barbero, 1981) to the south (e.g., Favaretto et al., 2008). Though some additional terrestrial data exist from shorter-span records, these often only provide information for the Middle Holocene onwards and thus mostly fall outside the chronological coverage of this review (e.g. Skadar Lake, Montenegro/Albania: Zanchetta et al., 2012). Our knowledge of the local impact of global climatic change thus remains patchy, although, as we will see, relatively consistent. The archaeological documentation is much more extensive, although again, still relatively limited when compared to the rest of Europe because of the local history of research and the political events of the last thirty years. The faunal and lithic assemblage information described below is primarily derived from site specific publications, and so varying levels of detail are available for discussion in each temporal context. As a result, it is often challenging to identify whether any pattern observed in data is linked to research biases, or somehow representative of past reality.

In order to enable comparisons between both the paleoenvironmental and archaeological record, a robust chronological framework using absolute dates is required. For this purpose, we rely upon an exhaustive database of radiocarbon determinations for archaeological sites assembled as part of an ongoing research project led by one of us (EUROFARM project: Vander Linden et al., 2013). The radiocarbon database covers the research area and adjacent regions such as Adriatic Italy, Albania, southern Hungary, western Romania, western Bulgaria, and northern Greece. From a chronological point of view, collected data span between the Glacial Interstadial 1 (GI-1, or Bølling-Allerød) and the Middle Holocene (*c*. 13,500 to 5,000 uncal. BP; that is *c*. 16,000 to 5,700 cal BP). Entries found in the database are recorded as uncal BP since the calibration procedure is already an interpretation of the data; all dates found here are reported as cal BP, after calibration using OxCal 4.2 (Bronk Ramsey, 2009) and IntCal 13 (Reimer et al., 2013). The adoption of such large chronological brackets enables the exploration of the long-term trajectory of Terminal Pleistocene and Holocene foraging populations, as well as the introduction of early farming and its local development over more than a thousand years.

At present, the radiocarbon database consists of 2,275 radiocarbon dates from a total of 423 sites. After compilation of all known existing records, the database was subject to extensive auditing, including the removal of obvious outliers. We adopted a maximal threshold value for standard deviations of 200 years for dates older than 10,000 uncal BP and 150 years for dates younger than 10,000 uncal BP. Whilst such thresholds are necessary to ensure the overall quality and precision of the database, they also lead to a relative loss of accuracy, causing some poorly dated sites to be excluded entirely, a negative side-effect that must be kept in mind, especially for older periods (see below). The database also presents numerous quantitative and spatial biases. Table 1 summarises the number of radiocarbon determinations available per chronological period and representative countries. Two conclusions stand out: first, the number of dates for the Neolithic period outstrips the corresponding information for the Late Upper Paleolithic and Mesolithic by a factor of four, despite the fact that they lasted over twice as long; second, there are marked discrepancies between values per country which cannot be accounted for by differences in total areas. For instance, the availability of dates for the Mesolithic is highly skewed by the density of research and 14C determinations for the Iron Gates (Serbia). Although such biases have to be taken into consideration throughout the analysis, their existence does not prevent the scientific usefulness of the overall radiocarbon dataset.

These potential biases thus being kept in mind, the main methodological challenge lies in identifying adequate ways to describe such a relatively large dataset. For this purpose, we have resorted to summed calibrated date probability distributions (hereafter SCDPDs), using a revised version of the method originally devised by Timpson and colleagues (i.e. comparison of summed data with a null model, and statistically significant differences between both being considered as potentially meaningful; Timpson et al., 2014; see Vander Linden et al., submitted). This method assumes that any regional radiocarbon record reflects the magnitude of past activities, so that fluctuating densities of radiocarbon dates are informative of the intensity of past human settlement, including past demography. As discussed in several publications (e.g. Rick, 1987, Chiverrell et al.

2011, Williams, 2012), many factors – e.g. taphonomy, history of research, shape of the calibration curve – are likely to blur this suggested one-to-one relationship and must be taken into consideration in the interpretation of these radiocarbon distributions. Quality control and critical auditing of the database, as conducted here, allows to tackle some of these issues (e.g. uncertainty related to the link between the 14C determination and the event to be dated), as does the addition of the statistical procedure used here (e.g. factoring peaks and plateaus in the calibration curve by removing false outliers: Timpson et al., 2014). This being said, several recent papers demonstrate that the technique works best when the radiocarbon signal is combined with other categories of information, such as paleoenvironmental records and 'traditional' archaeological data, as we do here (e.g. Woodbridge et al., 2014, Lillios et al., 2016).

The following presentation of data is therefore organised according to the main global climate periods, with summaries of the corresponding regional changes in environment. These are then compared with the trends observed in the SCDPDs, including mapping of the associated archaeological evidence to detect possible modifications of the settlement pattern. In order to provide a first order of geography, the SCDPDs have been calculated on two sub-sets of the 14C database, by making a distinction between 'inland' (i.e. Danube catchment) and 'coastal' areas (i.e. Adriatic catchment). Lastly, a more detailed presentation of the key archaeological sites is offered, in order to identify and characterise environmentally driven human behaviours not captured by the radiocarbon record.

4. Paleoenvironmental and Archaeological Data: Results

4.1 Terminal Pleistocene

Glacial conditions reached their maximum extent during the LGM approximately 22,900-17,000 years before present (Lowe et al., 2008). During this time, the Balkan Peninsula was a refugium for plant and animal species (Rossignol-Strick et al., 1992, Spry-Marqués, 2012, Willis, 1994). Conditions were dry, but pollen evidence suggests the presence of both coniferous and deciduous taxa, with the latter being located in microenvironmentally “friendly” locations, such as humid areas and south-facing slopes (Willis, 1994). In the late glacial, global climate became milder as glaciers retreated. Geoarchaeology, micromorphology, and examination of pollen data from cave sites and sediment cores in the northern Adriatic all suggest that the Trieste Karst was a harsh, unwooded landscape experiencing cold and dry environmental conditions during the late glacial which persisted into the terminal Pleistocene and early Holocene (Boschian and Fusco, 2007). These environmental conditions may have created a northern barrier to the movement of human populations during a time of increasing sea level further south.

The distribution of sites dating to the late Pleistocene in the northeastern Adriatic is constrained by geomorphological transformations following deglaciation. In the north, few sites are located in the Trieste Karst, likely due to erosional processes affecting site preservation (Boschian and Fusco, 2007). Further south on the Istrian Peninsula, the earliest evidence for upland site use begins around 15,000 years BP (Komšo, 2006) and in Dalmatia the archaeological record spans from the LGM.

4.1.1. GI-1 (Bølling-Allerød; 14642±186 to 12846±138 cal BP)

Glacial Interstadial 1 (hereafter GI-1) is characterised by an overall rise in temperature, with a further five sub-events being recognised in the NGRIP ice-core (GI-1e-a; Blockley et al., 2012, Rasmussen et al., 2014). GI-1e presents a rapid rise in temperature, observed regionally in Slovenia and Romania, whilst GI-1d is seen as relatively stable with a warmer and drier environment at Lake Bled from 13.8ka cal BP onwards (Feurdean et al., 2014). At Lake Ljubljana in Slovenia, groundcover was composed of open mixed pine and birch (*Betula*) woodland (Andrič et al., 2008). In and around the Great Adriatic Plain, multiple proxies including plant pollen and macrofossils, sedimentology, and molluscs from Lake Vrana and Valun Bay on the isle of Cres suggest open grassland vegetation in the late glacial (Schmidt et al., 2000). GI-1c-in both Slovenia and Bulgaria present a greater diversity in tree taxa, indicating the presence of fragmented temperate deciduous forests, also observed, but not expanding at this point, in Bulgaria (Feurdean et al., 2014). Likewise, Aufgebauer and colleagues (2012; see also Bordon et al., 2009) record relatively stable hydrological conditions at Lake Prespa through the entire GI-1 period, with a temperate deciduous forest still mainly dominated by *Pinus*, but with a growing proportion of *Quercus* as well as increase in diversity of trees, which are gradually moving out of their LGM refugia.

During the LGM, global sea level was approximately 130m lower than present day (Lambeck et al., 2002). The Great Adriatic Plain extended south to Zadar, Croatia and across to Pescara, Italy (Lambeck et al., 2004, Surić, 2005) and was covered with many rivers originating from the northwest (Ferretti et al., 1986). Following deglaciation, the level of the Adriatic Sea rose rapidly, but not at a constant rate (Lambeck et al., 2004). It left a series of coastal erosional and depositional features across the northern region as it rose during warmer periods and halted during cooling oscillations such as the Younger Dryas.

Unfortunately, the precision of the divisions and concomitant short-term oscillations recorded in the INTIMATE stratigraphy cannot be directly matched with the very limited archaeological record available for our research area. The SCDPDs do not record anything for the inland region, apparently devoid of any site at that period, whilst the Adriatic data show a very low signal, corresponding to a handful of sites from the Western Adriatic as the Alps become available for human settlement following deglaciation and foragers exploited karstic prey such as chamois / ibex (Figure 1) (e.g. Phoca-Cosmetatou, 2002). There is a single upland cave site with early evidence for use, Nugljanska, located in Istria, Croatia (Komšo and Pellegati 2007, Miracle and Forenbaher, 2000) and the lowest levels have been dated to 15,077–14,212 cal BP and 13,225–12,845 cal BP (Pilaar Birch and Miracle, 2015). It may have been a hinterland outpost at this time (Komšo, 2006, Miracle, 2007). There are a large number of stone tool classes in the Late Upper Paleolithic. This decreases in the uppermost Paleolithic layers, when there is a large increase in hunting tool-types and burins made of regional material. Virtually no local or exogenous materials are incorporated into the tool set (Komšo and Pellegatti, 2007). Faunal remains suggest an increasing focus on migratory red deer through this period, a steady but partial reliance on caprids and suids, and decreasing numbers of aurochs (Pilaar Birch and Miracle, 2015, Pilaar Birch et al., 2016). At least one additional site is known for this period on the Croatian Adriatic coast, but was not included in the database because of the large standard deviation attached to it. The site of Kopačina, located on the isle of Brač, dates to 14,691-13,116 cal BP (Z-2404: 11,850±220 BP; Miracle, 1996). Excavations throughout the 20th century yielded lithic and bone artefacts, terrestrial faunal remains, marine molluscs and fish, land snails, and multiple hearths (Čečuk, 1996, Miracle, 1995, 1996, Paunović et al., 1999). Lastly, for Montenegro, Mihailović mentions the possibility of the re-occupation of hilly zones during GI-1 on the basis of the typological attribution of various assemblages (Crvena stijena VIII, Medena stijena VII_V, Trebački krš 2, and possibly Mališina stijena layer 2; Mihailović, 2004).

4.1.2. GS-1 (Younger Dryas; 12846±138 to 11653±99 cal BP).

Glacial Stadial 1 (hereafter GS-1) presents a sharp transition to a sustained change in climate and a halt in sea level rise in the Adriatic. During this time, average temperatures declined significantly, especially for the winter, as did overall precipitation, leading to an expansion of the dry steppe and a concomitant fragmentation of the boreal forest (Willis, 1994, Feurdean et al., 2014). Pollen from pine, *Artemesia* and chenopods in a southern Adriatic core dated to the end of GS-1 in the region suggest very dry conditions characteristic of steppe environments (Favaretto et al., 2008; see also Combourieu-Nebout et al., 2013). At Lake Prespa, there is a marked decrease of *Pinus* from 13.2 cal BP (i.e. corresponding to the start date of GI-1a; Rasmussen et al., 2014), with associated expansion of chenopods pointing to a similar pattern of decreased temperature and increasingly arid conditions. In this particular location, this process culminates around 12.6 cal BP, and is followed by a re-advancement of trees, indicating warmer and more humid local conditions.

Interestingly, and despite possible assumptions regarding the negative impact of harsher climatic conditions upon human settlement, the SCDPDs actually show a small rise, corresponding to a series of sites from the Western Adriatic (Figure 2). In addition to a couple of sites from southern Italy (Grotta della Mura, Grotta Romanelli), the settlement pattern is characterised by a cluster of sites in the peri-Alpine region. As recently showed by Mussi and colleagues (2011), there is a limited change in the settlement pattern of the latter region, with the use of new, generally smaller sites, but otherwise very limited change in hunting behaviour.

For Eastern Adriatic, the database comprises few entries, including the site of Nugljanska introduced above, which may have been a residential base at this time (Komšo, 2006, Miracle, 2007). As for the previous period, the faunal assemblage is dominated by red deer, followed by suids and caprids (Pilaar Birch and Miracle, 2015). It is possible that the site was used as a primary target for preying upon red deer, but the presence of other smaller game prevents from interpreting this pattern as clear indication of specialised hunting. Another site dated to this period is the cave of Pupićina, in Istria, Croatia, excavated from 1995-2002 and extensively published (Miracle, 1997, 2001, Miracle et al., 2000, Miracle and Forenbaher, 2000, 2006). The uppermost Late Upper Paleolithic occupation layers have been dated to 12,460 cal BP and contained a large number of lithic tools, cores, flakes, and debris from regionally sourced flint (Miracle, 2001). There are also some tools constructed from local and exogenous sources, further suggesting that it was a central place within a large territory within which people were moving and obtaining raw lithic material (Komšo and Pellegatti, 2007). Approximately half of the faunal remains are red and roe deer, with the remaining assemblage comprised of increasing amounts of wild boar and decreasing numbers of caprids and aurochs through this period.

4.2 Early Holocene (including Pre-Boreal, Boreal, and oscillations; 11653±99 cal BP to 8090±45 cal BP)

Following the suggestion recently put forward by Walker and colleagues (2012), we are here using the simplified division of the Holocene into Early, Middle and Late categories, with the early Holocene lasting between c. 11,650 cal. BP and marked by three short oscillations respectively at 11.4, 9.3, and finally 8.2 ka cal BP (Rasmussen et al., 2014).

Woodland expanded during the Early Holocene, but its extent would have been restricted by rising sea levels in the Adriatic. Overall, the changes are parallel to the sequence recorded by Greenlandic ice cores, although the magnitude of change was less dramatic in continental than in western, Atlantic Europe (Feurdean et al., 2014), with vegetation transitioning from dry adapted species to a mixed deciduous community, reflecting increased moisture availability (Favaretto et al., 2008). High sedimentation rates reflect a rapid influx of sediment sources, driven by rapid post-glacial sea level rise. There is a general increase in tree pollen; however, peaks of juniper, *Artemisia* and chenopod pollen suggest smaller cool and dry oscillations occurring during this time, perhaps relating to the 11.4 ka event (the so-called Pre-Boreal Oscillation). Evidence from foraminifera suggest less mixing and a warming of Adriatic surface water during the Pre-Boreal, from 11,500 cal BP to 10,800 cal BP (Favaretto et al., 2008).

Taken together, these proxies suggest a rapid expansion of mixed deciduous woodland throughout the Balkans between 10,500-9,500 years BP (Balbo et al., 2006, Willis, 1994). There is evidence for mixed oak and pine forest in Trieste, Italy (Voytek 2011) and mixed oak and hazel (*Corylus*) further north in Ljubljana as well as in the south (Andrič et al., 2008, Favaretto et al., 2008). The spread of deciduous taxa was facilitated by the presence of refugial Pleistocene populations, and the makeup of the woodland at the Pleistocene-Holocene transition is more diverse at higher elevations (Willis, 1994). There was increased disparity in average seasonal temperatures (from an estimated -15°C in winter to 10°C in summer; Favaretto et al., 2008). In the southern and central Adriatic Sea, there is evidence for rising temperatures and increased precipitation based on the increase (between 10,000-9,000 cal BP) in oak pollen (Rossignol-Strick, 1999); a trend also seen in cores further north in the Adriatic, based on pollen and mollusc proxies (e.g., Schmidt et al., 2000).

The climate of the eastern Adriatic was mild and wet, near present-day conditions, by around 9,000 cal BP (Rossignol-Strick, 1999), with evidence for an increase in local humidity at the end of the Boreal (Andrič et al., 2008). Conditions were still warm-temperate and perhaps less variable, with winter temperatures only ranging from -2°C to 5°C (Peyron et al., 1998). The presence of beech supports a mean temperature of 9°C and 1200mm precipitation per annum during this period (Delhon and Thiebault, 2005).

The northern third of the Adriatic Sea was formed in the first half of the Holocene as both sea level and the inland freshwater table continued to rise. The Dalmatian Islands were formed as a result of the inundation of several small mountains, and many remained within sighting distance, possibly leading to prehistoric island-hopping and trade (Forenbaher, 2009). The Kvarner Gulf began to form around 8,500 years ago, reaching full marine conditions by 7,920 cal BP (Surić et al., 2005). A well-developed former shoreline at -25m (Colantoni et al., 1979) may indicate a hiatus in sea level rise associated with climatic cooling during the 8.2ka event (see also Zecchin et al., 2015 on the possible uneven nature of the Holocene Adriatic sea rise). The present shoreline was likely formed by around 6,000 years ago (Lambeck et al., 2004).

From an archaeological point of view, the SCDPDs for both maritime and inland areas present a relatively constant record for the entire duration of the early Holocene, with few oscillations of no strict statistical significance (Figure 3). The sole exception concerns a small peak of values in the Adriatic SCDPDs around 11,500-11,000 cal BP, likely to be related to the unusual shape of the calibration curve for this period. It must however be noted that the inland record, that effectively corresponds to the Iron Gates, does present some fluctuation towards the end of the period, which is discussed below.

The early Holocene archaeological record is characterized by Mesolithic cave and open air sites, followed by the introduction of agricultural lifestyles throughout the region, beginning further south and moving northwards throughout the middle Holocene (see below). The state of affairs in the Adriatic catchment has benefited of numerous projects over the past twenty years or so. For instance, in the Istrian Peninsula, the majority of the sites were discovered and excavated as a result of the "Pupićina Cave Project" and subsequent "Paleolithic and Mesolithic settlement of the Northern Adriatic Project" (Komšo, 2006, Miracle, 2007). This included cave sites (Šebrn Abri, Jačmica, Klanjčeva, Vela, Pupićina, Nugljanska, and Vela Špilja on the island of Lošinj, as well as two sites not reviewed further, Sklepova and Ovčja) and open air sites (Lokve and Kotli; the latter is not reviewed here) in the period 1995-2005. In addition, five open-air Mesolithic sites (Kostadini, Frankoli, Marišće, Kralji and Žiganti) were found during survey of Čepić Polje, a drained lake slightly south of Pupićina, leading to the excavation of the largest one, Kostadini, discussed below (Balbo et al., 2009). There are only a few confirmed Mesolithic sites in Dalmatia, most of which are found in caves. There is need for further research on these smaller sites, which include Kopačina, described above, Vlakno, below, and Zemunica (not reviewed further). The largest and best understood site is Vela Spila on the island of Korčula, which is notable because of its size and rich cultural deposits, also described in further detail below.

The Istrian sites present an interesting case for increasing settlement of the area based on the collective record of faunal and lithic remains. At the rockshelter site of Šebrn Abri, use dates to an approximately 800 year interval beginning at 10,460 cal BP, including Mesolithic stone tools and a faunal assemblage, with perforated specimens of *Columbella* shells present (Miracle et al., 2000). Located above a steep valley, the site is 750m above sea level and has been proposed as a place of lithic production as well as a hunting station (Komšo, 2006, Miracle et al., 2000). Jačmica is located at an elevation of 380m above sea level in the north of the Istrian Peninsula (Crismani, 2003, Komšo and Miracle, 2005). Mesolithic stone tool types including endscrapers, backed bladelets and burins were found along with mammalian faunal remains and land snails. Site use was interpreted as intermittent, by small groups of foragers throughout the Mesolithic period (Komšo, 2006). Klanjčeva cave has a reversed chronology, with a layer dated to 9,510 cal BP underlying the uppermost layer dated to 11,220 cal BP. Though the site possesses lithics characteristic of regional Mesolithic assemblage types, the contested stratigraphy makes it difficult to assign significance (Miracle and Forenbaher, 2000). The lowest excavated level at Vela cave (located directly across from Pupićina) was dated to 11,613-10,556 cal BP (9,680±170 BP; Beta-145093) (Radović et al., 2008). Similar to Mesolithic levels at Pupićina, the fauna at the site consists of red deer, boar, hare, and chamois, as well as hedgehog and badger, and winter use has been suggested based on a single specimen of red deer (Radović et al., 2008). The Mesolithic at the site of Pupićina, introduced above, is securely dated between 10,000-7,500 cal BP, during which time a permanent stream would have flowed on the valley floor (Komšo, 2006, Miracle, 2001). Perforated shells of the marine mollusc *Columbella* as well as freshwater species have been found in these layers. The site has been interpreted as a regional base camp in a settlement system of which Nugljanska and the cave of Vela Špilja on the island of Lošinj would have been a part (Komšo, 2006, Miracle, 1997, 2001). At Vela Špilja, a chert flake and burin are typical of Mesolithic stone tool types, and the early Holocene faunal assemblage is dominated by wild caprids (Pilaar Birch and Miracle, in press).

The two most promising open air sites in Istria include the sites of Lokve and Kostadini. The location of Lokve at a very high elevation (915m) in the Ćićarija Mountains 9km northwest of Pupićina makes it unique in the region. Over 21.5m^2 were investigated during two field seasons; the total extent of the site is estimated at 700m^2. No organic remains were recovered due to poor preservation, and the site is dated based on the recovered lithic material, which included late Mesolithic stone tool types. Based on this evidence it has been interpreted as an open air camp likely used for hunting activities (Komšo, 2006). In contrast, Kostadini is on the edge of a flat area formerly covered by a shallow lake and contained hunting and maintenance tools. The site was located at an advantageous spot, approximately 500m from the bottleneck of the lake, 45m above the lakebed, and 250m from a year-round spring. Despite the lack of faunal remains or additional material culture, it has been interpreted as a field or base camp used for diverse activities (Komšo 2006). Its large size and prime location at the crossroads of what was a waterway and potential land thoroughfare in the Mesolithic make it notable (Balbo et al., 2006).

In Dalmatia, a test pit was excavated at Vlakno Cave on the island of Dugi in 2004 and yielded lithics and remains of terrestrial and marine fauna dating to the Mesolithic, between 10,200-10,500 cal BP (on marine shell; Z-3382) and 11,400-12,000 cal BP (Z-3383) (Brusić, 2005). Vela Spila has very early dates for the Late Upper Paleolithic and has been proposed as a glacial refugium site (Spry-Marqués, 2012); these dates range between 17,500-15,000, when the cave would have been approximately 20km from the coast and 230m above sea level (Čečuk and Radić, 2005). In the Mesolithic, the site was close to its modern elevation in the Mesolithic, between 9,200-8,000 cal BP (Čečuk and Radić, 2005, Komšo, 2006). Special finds include three child burials, a number of adult burials, pierced *Columbella* shells, and stone tools crafted from Italian flint. There is debate over the

Mesolithic-Neolithic transition at the site, as ceramics and domestic ovicaprines overlap with Mesolithic-type material, and dates for the Neolithic are very early, suggesting a coastal route for the spread of agricultural lifestyles (Forenbaher and Miracle, 2005).

Several Mesolithic cave sites are also known in Montenegro, mostly located to the North and West of the country (e.g. sites of Trebački krš and Medena stijena: Mihailović, 2004). The rockshelter of Crvena stijena, set in a karstic environment overlooking the Trebišnjica River, presents a continuous stratigraphic record spanning the Pleistocene and the Holocene, including Mesolithic levels dated between 10,000 to 8,400 cal BP (Baković et al., 2009). Typological analysis of the lithic assemblage suggests links with the so-called Castelnovian industry, and is characterised by a wide range of blades and bladelets, including denticulated blades, double notches, trapezes, as well as endscrapers made on flakes (Mihailović, 2004, p. 103). A comparable lithic assemblage is known from the site of Odmut, located by the Vrbnica river and excavated in a rescue context in the 1970s (Kozłowski et al., 1994). While a proper zooarchaeological report was never published, preliminary information has recently been made available, and shows that ibex and red deer are the dominant species, followed by roe deer, chamois, wild boar and small carnivores (e.g. marten, fox), as well as unidentified fish remains. Other finds include numerous bone harpoons, pointing to a relatively late appearance of the technology in the area during the course of the 9th mill. cal BP (Cristiani and Borić, 2016). Typologically-related bone harpoons were discovered at Vruća pećina, a small rockshelter set high on hill side controlling the Morača river valley. Earlier excavations were conducted in the 1990s, followed by a control excavation in 2014 as part of the EUROFARM project. This work has confirmed the presence of Mesolithic levels, dated to the 9th and 8th mill. cal BP, associated with a small faunal assemblage dominated by red and roe deer, wild boar and smaller carnivores. Lastly, it is also worth mentioning the recent discovery of the site of Seocka pećina, the only Mesolithic site known to date by the shores of the Skadar Lake (Vander Linden et al., 2015). All deposits are unfortunately in secondary position, but contained a coherent zooarchaeological assemblage with wild fauna and fish remains, plus lithics, including blades, dated by an extended series of 14C dates between 10,700 and 9,100 cal BP.

Although an exhaustive survey of all Mesolithic faunal assemblages found along the eastern Adriatic coast lies beyond the remits of this paper (but see Pilaar Birch, 2012), the data presented here point towards a recurrent pattern, characterised by a marked preference for wild caprids such as chamois and ibex, red and roe deer, and wild boar (Pilaar Birch et al., 2016; Pilaar Birch and Miracle, 2015, in press, Miracle, 2001, 2002, 2007). In numerous instances, faunal assemblages also include a range of fishes and other aquatic animals, suggesting that marine and riverine resources contributed in some way to the diet of early Holocene foragers. Stable isotope analysis supports this impression; though rare, human bone samples from the Croatian sites of Vela Spila and Pupićina suggest that, "while the Mesolithic people of the Adriatic coast consumed some marine protein, terrestrial protein constituted a significant part of their diet" (Lightfoot et al., 2011, p. 82; see also Paine et al., 2009).

The restricted distribution of confirmed Mesolithic sites located in the Danube catchment is partly related to the history of research, but also informative of a certain past reality. For Croatia, a few possible open air sites are reported in the Požega basin, but Komšo (2006) warns that a majority of these should be viewed critically and some outright rejected due to lack of proper excavation and dating. For Bosnia and Herzegovina, small lithic assemblages from the sites of Ruživa pećina (Herzegovina) and Pećina pod lipom (eastern Bosnia) have been assigned to the Mesolithic on typological grounds (Kujundžić-Vejzagić, 2001, 2005), but this identification is far from assured. So far, the only certain Mesolithic site comes from Rastuša, a small cave located in northern Bosnia. A single Mesolithic level, found towards the entrance of the cave, contained a small lithic assemblage, and is radiocarbon dated to c. 9,800 cal BP (Jovanović et al., 2014). Otherwise, the available documentation is thus mostly confined to the exceptionally rich record of the Iron Gates, where excavations undertaken for several decades have revealed numerous well-preserved sites such as Lepenski Vir, Vlasac and Ogradena-Icoana (see recently Borić et al., 2014; Bonsall et al., 2015a, 2015b, Nehlich and Borić, 2015).

Over 20 Mesolithic sites have been documented along the Danube Gorges in Serbia and Romania; the majority of these are open air sites (Borić, 2002, Dinu et al., 2007). The relationship between radiocarbon dates and cultural horizons has been much debated in this region and many disparities cannot be resolved because of the destruction of the sites by flooding caused by damming (e.g., Bonsall et al., 1996, 1997, Borić, 2002, Dinu et al. 2007 and references therein). The most famous site is that of Lepenski Vir, which spans the transition from the Mesolithic to the Neolithic. The earliest date for Mesolithic occupation at Lepenski Vir is between 9,550-9,950 cal BP (Borić, 2002). The area surrounding the sites was likely forested in the early Holocene based on the faunal remains and the river would have been a main feature in the landscape (Borić, 2002). Though it is very different in nature from the other sites reviewed here, and despite its contested cultural sequence, it is very interesting because the presence of trapezoidal floors potentially associated with Mesolithic material culture has led to the idea of affluent, sedentary Mesolithic foragers. However, Borić (2002) warns that a complex seasonal schedule of subsistence activities may conflict with the interpretation of sedentary fisher-hunter-gatherers and that there may be a significant gap between the Mesolithic of what he calls “Proto-Lepenski Vir” and the early Neolithic Lepenski Vir associated with permanent structures.

The faunal remains were originally analysed by Sándor Bökönyi in the 1960s, but further study has been difficult because only a small portion of the original sample, which was hand-collected and derived from under house floors, was saved at the National Museum in Belgrade (Dimitrijević, 2000). Bökönyi (1970) described the fauna in three phases, and noted that the earlier two were thought to represent the period before the arrival of the pottery Neolithic in the Balkans (i.e. Mesolithic), while the later phase represented the earliest Neolithic. The earliest phase was thought to be associated with trapezoidal floors, which Bökönyi (1970) suggested were shrines rather than houses, based on the presence of articulated faunal remains (interpreted as sacrifices) and red deer skulls with antlers. He reported that dogs were the only domestic animal found in the first two phases and that the remainder of the faunal assemblage was heavily dominated by fish (over 50% in the first phase) and red deer. In the third phase, domestic sheep, goat, cattle, and pig appeared in moderate frequencies, but wild fauna still comprised a portion of the assemblage, especially roe deer. He also noted a decrease in relative abundance of fish taxa in the third phase, though sample sizes for the earlier two phases were small compared to the third phase.

As mentioned above, these early interpretations and the complex history of the site have caused some controversy over the continuity of mobility patterns and subsistence at the site through time. Bonsall (1997, 2000) suggested a shift from the consumption of aquatic resources in the Mesolithic to terrestrial foods in the Neolithic based on results from stable isotope analysis of human remains, but this was contested by Borić and Dimitrijević (2007), who argued that freshwater fish and terrestrial mammals remained important throughout both periods at Lepenski Vir and the nearby site of Padina. This potentially highlights the disparity between comparing human stable isotopes to traces of food waste, but it led Borić (2002) to call for a more complex model for the nature of the Mesolithic-Neolithic transition in the region, since an economy based on fishing may be subject to seasonal scheduling as some fish (notably sturgeon in the Danube) migrate upriver at different parts of the year. In this case there may be implications for more nuanced seasonal relationships with other sites in the settlement system, which included Hajdučka Vodenica, Vlasac, and Padina, with similar chronologies and material culture. Currently, it appears that there was a shift from overall high consumption of fish in the Mesolithic to a larger proportion of terrestrial protein, though fish remained important, from 8,200 cal BP, with new evidence for possible consumption of domesticated grains even earlier, around 8,600 cal BP (Cristiani et al., 2016). This stands in contrast to the scenario for the Adriatic, where it appears that terrestrial protein always comprised the bulk of the diet. The rockshelter of Cuina Turcului is the only example of an upland context with Mesolithic cultural material with Pleistocene dates, and these too are contested (Dinu et al., 2007); however, they do not appear to overlap with occupation at the lowland sites. The Danube Gorges stands in contrast to the scenarios of seasonal aggregation and dispersal of human groups over a large area proposed for Late Upper Paleolithic Epirus and multiple season use and resource intensification during the Mesolithic at Franchthi (c.f. Gamble, 1986, Stiner and Munro, 2011). Whether used by sedentary, affluent hunter-fisher-gatherers or seasonally mobile foragers following a complex seasonal schedule of site use, the Danube Gorges provide an alternative example of how Mesolithic settlement and society may have functioned in the central Balkans.

Overall, the early Holocene archaeological record thus far points to a relatively constant and low population density. As the landscape undergoes a drastic transformation (although admittedly less so than in other regions of Europe), there is a corresponding human response most noticeable in new settlement patterns. Following the initial suggestion by Runnels (1995), and recently reconsidered by Gurova and Bonsall (2014), it indeed seems that the extensive forest cover that proliferated following deglaciation very well could have constrained the range of possibilities for human settlement. This, coupled with the loss of the open terrain of the Great Adriatic Plain in the initial Holocene, corresponds to the apparent use of either ‘coastal’ upland (the modern Adriatic coastline and associated islands), riverine (Iron Gates, Skadar Lake) or hilly/karst environments (Montenegro, Istria, and to the west, the Appenines). This settlement pattern in each case would have been associated with the use of local lithic and plant resources, and also had implications for diet. For example, there is a focus on terrestrial faunal resources with only some mixing along the Adriatic catchment (cf. Lightfoot et al., 2011, Miracle, 2001, 2002, Pilaar Birch and Miracle, 2015, in press, Pilaar Birch in press) despite the encroaching coastline, perhaps attributable to the poor quality of the Adriatic fishery and the availability of karstic and woodland border species such as caprids and deer. In contrast, there was a stronger focus on fish in Iron Gates in the Mesolithic due to the productivity of the Danube River system, accompanied by a use of terrestrial resources. Though both would likely have relied upon species that were only available or desirable at certain parts of the year (such as red deer in the Adriatic and sturgeon in the Danube), but potentially supplemented these with additional food resources such as non-migratory species in the case of the Adriatic, and, possibly, domesticated grains in the Iron Gates.

4.3 8.2kya event and the spread of early farming (8250±49 cal BP to 8090±45 cal BP)

The 8.2 cal BP event is, in Walker and colleagues’ new classification (2012), set as the limit between the early and middle Holocene, a decision related to its unambiguous large-scale climatic and environmental impact. Yet, despite an increasing number of publications, the local dimensions of this event, and in particular the potential human responses, have proven difficult to assess. For Europe, Magny and colleagues infer a zonation of hydrological regimes, with increased aridity and seasonality south of a Valencia-Napoli-Athens line and, by contrast wetter and cooler climate across the northern Mediterranean and central Europe (Magny et al., 2003; see also Berger and Guilaine, 2009). A variety of local environmental archives supports their hypothesis, for example records in Lake Accessa in NW Italy and Tenagghi Philippon (Peyron et al., 2011) which suggest drier winters and wetter summers; the record from Lake Stymphalia (Peloponnese, Greece: Heymann et al., 2013); and the speleothem record from Ascunša (Romania, Drăguşin et al., 2014). Pross and colleagues (2009) have also put together strong arguments for disruption of climate signals during 8.2 ka event. In Lake Prespa, the event is marked by a decline of 10% in arboreal species and a concomitant increase in steppic taxa, with a decrease in overall precipitation recorded by accumulation rates and nature of herbs and algae from 8.3-7.9 ka cal BP (Aufgebauer et al., 2012, Panagiotopoulos et al., 2013). Drier and cooler winter temperatures are recorded from Lake Maliq in Albania (Bordon et al., 2009) and Lake Dojran in Macedonia (Francke et al., 2013). This seems to be contrasted by a humid phase recorded in Lake Ljubljanska (Andrič et al., 2008) and a less distinct signal in the Adriatic, with evidence for only slightly decreased temperature and precipitation coupled with a decline in *Quercus* (e.g. Combourieu-Nebout et al., 2013).

While the environmental records thus confirm the hypothesis of a zonation of the region during the 8.2 cal BP event, the archaeological implications remain challenging, especially as this period partly overlaps with the introduction of food-production techniques across the area. Before considering this question, let us first evaluate the possible response to environmental changes by 'final' foraging communities. Across the entire Adriatic zone, the SCDPDs do not reveal any marked fluctuation, but detailed examination of the radiocarbon record points to a lack of data for the final centuries of the 9th mill cal BP (Figure 4). First recognised more than ten years ago (Forenbaher and Miracle, 2005), this documentary gap has since persisted despite the addition of numerous dates from different sites (Forenbaher et al., 2013). However, its interpretation remains open: given the still limited amount of evidence, it is not possible to rule out the effect of research biases. Alternatively, this gap could partly be explained by the multiplication, during the 8.2 cal BP event, of erosional events which would have either obliterated or washed away the already scarce Mesolithic settlement evidence (see Berger and Guilaine 2009). Lastly, this gap could represent a past reality and point to the relocation of the last foraging communities in the wake of the surrounding landscape changes (as for instance observed in the Iberian Peninsula: González-Sampériz et al., 2008). A similar drop in the radiocarbon record, this times recorded in the SCDPDs presented here, can be observed for the Danube catchment area, effectively for the Iron Gates. Bonsall and colleagues initially identified this pattern and suggested that this gap in an otherwise long-term continuous record could be related to flooding episodes, eventually driven by the climatic instability associated with the 8.2 cal BP event (Bonsall et al., 2002). While Borić and Miracle criticised the empirical foundation of this view (Borić and Miracle, 2004), it is noticeable that the initial trend is still observed despite a three-fold increase of the available number of radiocarbon dates (Bonsall et al., 2015). Rather than interpreting this drop as an episode of population depletion, Bonsall and colleagues rather suggest that it corresponds to a change in the annual water discharge of the Danube river, related to the hydrological regime caused by the 8.2 cal BP event, which, in turn, would have affected the fish productivity of the river and eventually the human use and settlement pattern of the area (Bonsall et al., 2015).

The link between the 8.2 cal BP event and the appearance of farming communities in Europe has been widely debated over the past fifteen years, with Weninger and colleagues offering the more extreme view by considering, in an overwhelmingly critical assessment of the evidence, that all dates prior to 8,200 cal BP should be considered unreliable (Weninger et al., 2006). Based upon this apparent absence of older dates, they concluded that the spread of early farming in this part of Europe was a direct consequence of improved climatic conditions after the end of the so-called 8.2 ka cal BP cooling event. However, several sites have now yielded secure radiocarbon dates that demonstrate, without a doubt, that farming was practised across Turkish Thrace, Greece and Bulgaria during the second half of the 9th mill cal BP (e.g. Lespez et al., 2013, Perlès et al., 2013, Karamitrou-Mentessidi et al., 2015).

This being said, the role of the 8.2 ka cal BP event in the process of European Neolithization should not be minimised. Indeed, the SCDPDs show a sudden rise by 8,000 cal BP, which corresponds to the spatial extension of farming across the Adriatic basin (Figure 5) and the Danube catchment area (Figure 6). The correlation between the local Neolithic sequence and the end of the 8.2 ka cal BP is impressive and extremely suggestive. Starker seasonal extremes identified in areas where the Neolithic lifestyle was already present could indeed have slowed down, if not halted, the potential diffusion of early farming communities. The precise relationship between climate and local farming regimes needs to be further elucidated using archaeologically-linked local environmental proxies for this hypothesis to be properly tested. There is also no need to assume that, once initiated, the

Neolithic expansion out of Anatolia was an inexorable process as, at the European scale, the spread of farming undergoes several comparable episodes of stasis and expansion (Bocquet-Appel et al., 2009). The 8.2 cal BP event may well have impacted upon these cycles (Bocquet-Appel et al., 2012), but other factors – demographic, economic, social – must also be considered (e.g. Orton et al., 2016, Vander Linden, 2011).

5. Discussion

Much of the Pleistocene was chaotic—a time of vast, abrupt climate changes. The Holocene climate has been much more stable in comparison, though there were still several notable climate oscillations, especially in the initial stages of this period. Large-scale data from North Atlantic ice cores are useful for broadly classifying climate change in the eastern Adriatic. The sensitivity of the Mediterranean region to the North Atlantic Ocean has been established (Allen et al., 1999, Hughes et al., 2006) and some terrestrial proxies such as speleothem and lake-level records show North Atlantic climate events as far east as Israel (Bar-Matthews et al., 1999, Bartov et al., 2003). Davis et al. (2003) provide reconstructions of the temperature across Europe for the last 12,000 years and suggest that differences in climate over the continent varied widely both seasonally and spatially, but that mean annual temperature increased almost linearly up until 7,800 years ago. Drastic environmental changes occurred within individual lifespans and within only a few generations, there were noticeable differences in landscape throughout Europe.

Global climate change at the Pleistocene-Holocene transition can be translated into regional environmental change using multiple proxy records, both direct and indirect. Increased temperatures and moisture availability are first seen during the Bølling-Allerød as forests spread to higher elevations. The proliferation of grassland and open shrub communities reflect the relatively cooler and drier conditions of the Younger Dryas. As warming progressed in the initial Holocene, deciduous forests once again spread until the alteration of groundcover associated with the arrival of agriculture in the region during the Atlantic period.

While the largest-scale impact of sea level rise was the disappearance of the Great Adriatic Plain, it is also important to keep in mind the smaller-scale ecosystem and microhabitat changes that occurred as lowlands transitioned from open grassland ecosystems to estuaries, wetlands and coastal ecozones during the early Holocene. Sediments overlying glacial fluvial layers in the Venice Lagoon have shown a gradual transition from a transgressive, marshy environment to an open marine setting throughout the Pleistocene-Holocene transition (Favero and Barbero, 1981). This is consistent with the processes described above, as the Great Adriatic Plain became flooded and submerged within a few thousand years, causing noticeable landscape, environmental, and ecological transformations on a human scale.

In this paper, we have reviewed the improvement of conditions during the Terminal Pleistocene (GI-1), which were associated with limited changes in overall human settlement, especially use of newly made available landscapes and prey, although seasonal movements unable to be tracked by the radiocarbon record were likely affected and are evident upon closer consideration of the archaeological records at individual sites. The return to colder conditions during GS-1 similarly did not appear to have a noticeable effect neither on settlement, as suggested by the radiocarbon record, nor on hunting techniques. In many respects, then, the climate, environment, and landscape changes during the Holocene had the most dramatic impact upon broad scale settlement patterns of local foraging populations. Overall demographic density, insofar as can be reliably inferred from SCDPDs, suggest relatively low density throughout the earliest Holocene, a trend paralleled by settlement pattern with focus either upon coastal environments, inland upland areas, and riverine basins, with an avoidance of lowland, presumably forested regions. This pattern changes most noticeably after the 8.2 cal BP event, as the introduction of farming lifestyles and the Neolithic in the region lead to a large increase in population as well as movement into previously unoccupied, forested regions that were soon cleared for agriculture.

6. Conclusion

It is a truism to state that human-environment relationships are not deterministic and that their evaluation thus requires in-depth analysis of extensive datasets. Although both archaeological and paleoenvironmental records available for our research area remain relatively spatially constrained, especially so in comparison with other European regions, we have shown how much climatic disruption towards the Late Pleistocene and the extensive reorganisation of all facets of the landscape during the early Holocene shaped human settlement patterns and behaviour. Such correlations become clearer over longer periods of time, as the low chronological resolution of the archaeological data often cannot be matched to the precision of short-term climatic oscillations. A noticeable exception here concerns the 8.2 ka event, for which a much larger contemporary archaeological dataset allows the identification of a robust correlation, although causation remains difficult to ascertain.

Given the diversity of data sources, and their uneven geographical and temporal distribution, it is necessary to consider in detail the possibility of shifting scales as part of the analysis. In this sense and from an archaeological point of view, the combination of SCDPDs, cartographic information and detailed account of individual sites demonstrates how human response to environmental changes can be identified and characterised at various congruent levels. We hope that, in the future, this combination of scales of analysis will allow to identify with precision gaps in our knowledge, and ways to fill them, a key issue especially in areas where research funding is often limited.

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Table 1. Distribution of radiocarbon dates per period/country.

Country	Mesolithic	Neolithic	Total
Albania	4	3	7
Bosnia and Herzegovina	1	116	117
Bulgaria		153	153
Croatia	21	205	236
FYROM		41	41
Greece	47	209	256
Hungary		308	308
Italy	133	292	425
Kosovo		2	2
Montenegro	23	11	34
Romania	86	112	198
Serbia	91	296	387
Slovenia	14	97	111
Total Result	420	1856	2275

Figure Captions

Figure 1. GI-1 (Bølling-Allerød)

Figure 2. GS-1 (Younger Dryas)

Figure 3. Early Holocene (Mesolithic)

Figure 4. Early Holocene (Neolithic)

Figure 5. Sum of all dates for the eastern Adriatic

Figure 6. Sum of all dates for the inland Balkans