The Neolithisation of Liguria (NW Italy): An environmental archaeological and palaeoenvironmental perspective

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The archaeological evidence compiled for Liguria has enabled the formulation of a comprehensive model of Neolithic social, technological and economic development (~7800–5700 cal yrs BP). The model indicates that during the Early and Middle Neolithic (~7800–6300 cal yrs BP; 'Impressed Ware' and 'Square Mouthed' pottery cultures) human activity mainly focussed on low (coastal) and mid-altitude areas. By the Late Neolithic (~6300–5700 cal yrs BP; 'Chassey' culture) farming practices were taking place over a wider range of altitudes and involved transhumant pastoralism. Complementary environmental archaeological and palaeoecological records from caves, open-air sites, lakes and mires indicate that human activities had a more significant impact on the environment than previously thought. This included clearance, especially *Abies*, *Ulmus, Fraxinus* and *Tilia*, and woodland utilisation and management (e.g. leaf foddering), as well as cereal cultivation and animal husbandry. The influence of Middle Holocene climatic changes, especially from ~7800 cal yrs BP, on the direction of vegetation changes and socio-economic developments during the Neolithic remain uncertain.

Keywords: Liguria, NW Italy, Neolithic, Archaeology, Palaeoecology, Climate Change

Introduction

There has been a long history of archaeological survey and excavation of Neolithic sites in Liguria, with a particular focus on caves situated in the western 'alpine' part of the region, and open-air sites in the eastern 'Apennine' area, where caves are scarce (Fig. 1). The archaeological importance of the region not only lies in the quality of data from these sites, but also because several caves, especially Arene Candide, appear to have the earliest records of Neolithic occupation for North-Central Italy (Maggi 1997a, 1997b, 1997c). The Early Neolithic '*Impressa Ligure*' Pottery Culture (~7800–7000 cal yrs BP) was a local aspect of the wider Impressed Ware Pottery Culture that introduced Neolithic technology into the northwestern Mediterranean. The succession from '*Impressa Ligure*' to the Square Mouthed Pottery (SMP) Culture (Middle Neolithic; ~7000–6300 cal yrs BP) is equally important because it is hypothesised that the SMP (Fig. 2) cultural tradition originated in Liguria and then spread across Northern Italy. Furthermore, Liguria is widely regarded as the 'gateway' for the spread of the Chassey Culture during the Late Neolithic (~6300–5700 cal yrs BP) from Southern France into Italy (Bagolini 1990; Bagolini and Biagi 1990; Crepaldi 2001; Binder and Lepère in press).

This paper integrates the existing environmental archaeological and palaeoenvironmental data from both eastern and western Liguria, and includes coastal to high altitude sites situated in a diverse array of geological and vegetational contexts. In western Liguria, intensive archaeological studies over several decades have led to the creation of an advanced model of human–environment interactions with detailed geoarchaeological and bioarchaeological (zooarchaeological and archaeobotanical) data (e.g. Arobba *et al*. 1987; Arobba and Caramiello in press; Biagi *et al*. 1987; Barker *et al*. 1990; Maggi 1990; Starnini and Vicino 1993; Branch 1997; Girod 1997; Macphail *et al*. 1997; Rowley-Conwy 1997). In eastern Liguria, the number of known Neolithic archaeological sites is considerably lower (e.g. Maggi 1983; Biagi *et al* 1987; Maggi 2014). Nevertheless, a number of high-quality palaeoecological records

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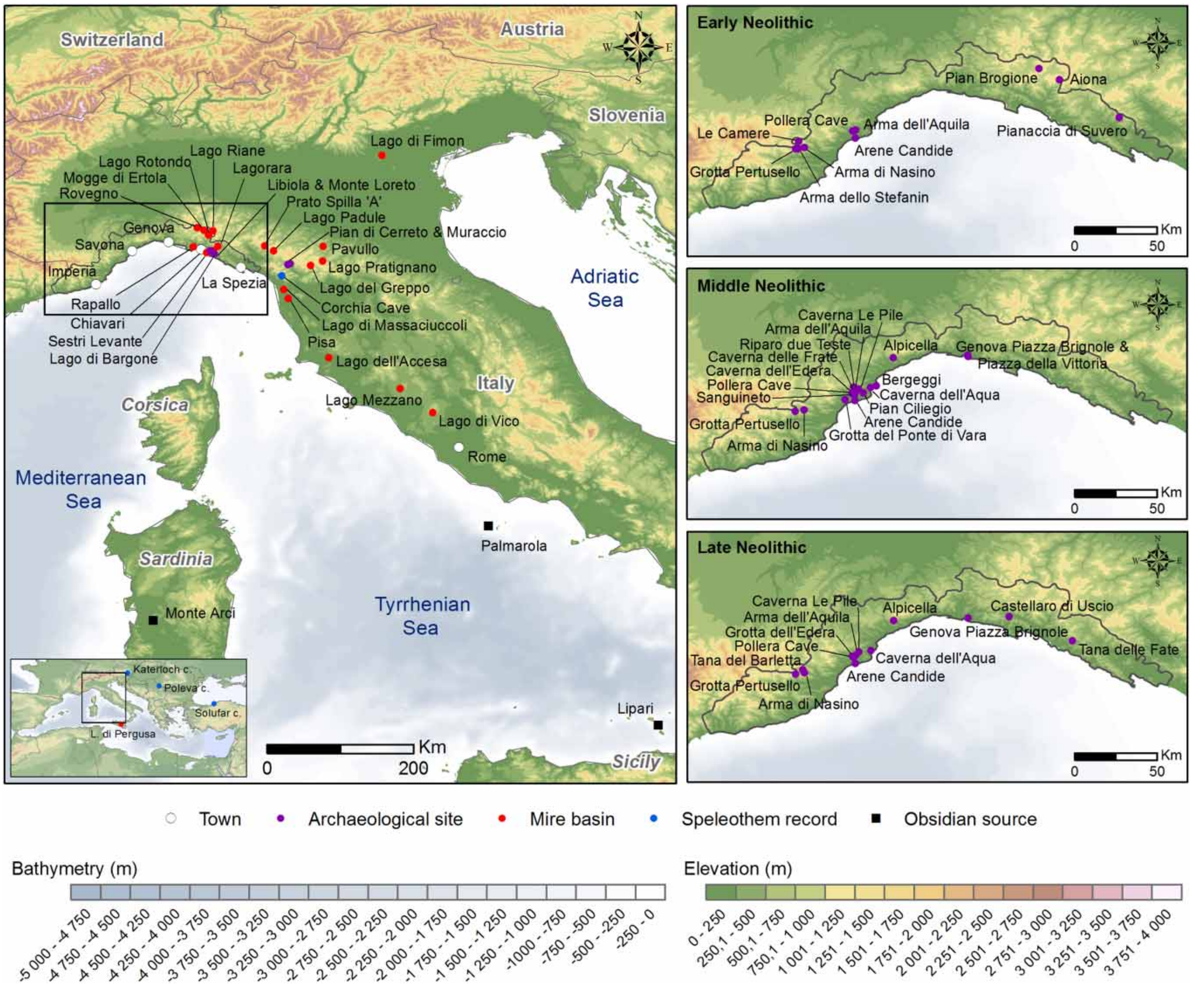

Figure 1 The location of Liguria (NW Italy), key palaeoenvironmental records from lakes, mires and caves, and Early Neolithic (~7800–7000 cal yrs BP), Middle Neolithic (~7000–6200 cal yrs BP) and Late Neolithic (~6200–5700 cal yrs BP) archaeological sites mentioned in the text (Leale Anfossi 1953; Tinè 1974; Arobba *et al*. 1987; Biagi *et al*. 1987; Melli and Lucchese 1987; Maggi and Del Lucchese 1988; Barker *et al*. 1990; Maggi 1990, 1996, 1997a, 1997b, 1997c, 1999, 2004; Lowe *et al*. 1994b; Magri and Sadori 1999; Ramrath *et al*. 2000; Sadori and Narcisi 2001; Arobba and Caramiello, 2006, 2009, in press; Ferrari and Steffè 2006; Spotl *et al*. 2006; Constantin *et al*. 2007; Drescher-Schneider *et al*. 2007; Zanchetta *et al*. 2007; Valsecchi *et al*. 2008; Bellini *et al*. 2009; Fleitmann *et al*. 2009; Del Lucchese 2010; Vescovi *et al*. 2010a; Branch 2013; Guido *et al*. 2013).

have enhanced our understanding of regional-scale environmental change over a wide altitudinal range (e.g. Braggio Morucchio *et al*. 1988; Cruise 1990; Branch 2002, 2004, 2013; Bellini *et al*. 2009; Cruise *et al*. 2009; Guido *et al*. 2013).

Collectively, these environmental archaeological and palaeoenvironmental records permit evaluation of the timing of Neolithisation in Liguria, and the social, economic and environmental changes throughout the Neolithic cultural period. They also allow appraisal of the spatial scale and intensity of Early and Middle Neolithic farming activities, and finally improved understanding of the environmental impact of human activities across the Ligurian landscape during the Late Neolithic, including the emergence of pastoralism at high altitude. The paper does not provide an exhaustive review of the archaeological evidence, or the radiocarbon chronology for the archaeological sites; the following discuss these aspects in detail: Bagolini and Biagi (1990); Barker *et al*. (1990); Skeates and Whitehouse (1994); Maggi (1997a); Pearce (2013).

Study Area

The region of Liguria is a predominantly mountainous area, 320 km long, with occasional abrupt transitions between the mountains and flat expenses of coastal plain or alluvial lowlands, such as the Albenga Plain in western Liguria (Fig. 1). There are key geological differences between eastern (Ligurian Apennines) and western (Ligurian 'Maritime' Alps) Liguria. Eastern Liguria is the northern-most section of the Apennine mountain chain, and dominating the geology are Limestone, Mudstone, Sandstone, conglomerates and breccias, and Ophiolites (Basalt, Serpentinite, Gabbro and Granite). Western Liguria is segmented by geological structures located in the Sestri-Voltaggio zone and is dominated by

Limestone, Schist, Quartzite, Gneiss, calcareous Rhyolites, and Mudstone, Sandstone, conglomerates, breccias, turbidites and calcareous Marl, as well as Ophiolites. Reflecting this complex geology is significant variation in soil properties, which also relate to a long history of human activities and land-use (see Walker 1960; Abbate *et al.* 1982; Hoogerduijn Strating *et al.* 1990; http://sgi.isprambiente.it).

The climate during the winter months is dominated by a permanent low-pressure system due to the influence of Atlantic depressions off the Spanish coast, local depressions and cyclogenesis in the western Mediterranean, and the influence of the Alps (the '*Maestrale*'). These are exacerbated by the sharp boundary between the sea and land along the coastline, and results in high rainfall from September to May (Genoa receives an average annual precipitation of ~1300 mm, while higher altitudes will receive in excess of 2000 mm). During spring and summer, the weather conditions are more stable, with high temperatures on the coast, reducing inland with elevation (Cantu 1977).

The present day vegetation cover has been influenced by the long-history of human activity, and may be summarised as follows (UNESCO-FAO 1969; Gentile 1982; Mariotti 1995; Blasi 2010):

1. The Mediterranean zone (from sea level to ~200 m asl) is characterised by xerophytic shrubland (macchia, e.g. *Erica arborea*, *Arbutus unedo*, *Cistus* spp.) and woodland dominated by *Q. ilex*, with *Quercus suber* and *Pinus halepensis*.
2. The sub-Mediterranean zone (~200–1000 m asl) characterised by thermophilous woodland with *Quercus pubescens*, *Q. petraea*, *Ostrya carpinifolia*, *Fraxinus ornus*, *Carpinus betulus*, *Acer campestre* and managed woodland of *Castanea sativa*.
3. The Montane zone (~1000–1500 m asl) is dominated by *Fagus sylvatica*, with *Quercus cerris, Acer pseudoplatanus* and *Fraxinus excelsior*.
4. The sub-Alpine zone (from ~1500 m asl) with coniferous woodland dominated by *Pinus sylvestris*, *P. cembra*, *Larix decidua* and *Abies alba* in the Ligurian Alps, and *Pinus mugo*, *Juniperus* and Ericaceous heath in the Apennines.

Synthesis of the Environmental Archaeological Records and Archaeological Context

Early Neolithic (Impressed Ware Pottery Culture)

The cave of Arene Candide is widely regarded as the 'type site' for the Neolithic in the north-west Mediterranean (Figs. 1 and 2A). Investigated by a series of excavations (Bernabò Brea 1946, 1956; Maggi 1997a; Tinè 1999a, 1999b), it provides one of the most detailed Late Pleistocene and Holocene stratigraphic sequences in Italy. The main characteristics of the Early Neolithic at Arene Candide include good quality pottery with the surfaces often polished using pebbles, bone or wood, and frequently decorated by impressions using a wood/bone stick or by the edge of a *Cardium* shell before firing (Maggi and Starnini 1997). Some of the largest vessels were manufactured from clay that was sourced no less than ~50 km from the cave (Ferraris and Ottomano 1997) with the furthest clay sources from eastern Ligurian Ophiolites, and possibly from Tuscany and Corsica (Capelli *et al.* 2006). The stone artefacts include those made of very good quality 'Bedoulien' flint from southern France (160–200 km away), red jasper from the Apennines (80–100 km away), 'Scaglia rossa' flint from central Italy (150–300 km away), as well as obsidian from the islands of Palmarola (Tuscany archipelago) and Sardinia (Monte Arci) (Ammerman and Polglase 1997; Negrino and Starnini 2003). A few glossed sickle blades are present of Early Neolithic age (Starnini and Voytek 1997a; Starnini 1999). The overall typology does not link the industry with the northern Italian and southern French Late Mesolithic (Biagi *et al.* 1993; Starnini and Voytek 1997a, 390).

Several radiocarbon dates indicate that the earliest Neolithic settlement of western Liguria commenced around 7800–7700 cal yrs BP (Binder *et al.* 2008; Pearce 2013). At Arene Candide, a seed of barley (*Hordeum*) has provided a date of 7740–7590 cal yrs BP (Beta-110542). Therefore, Neolithisation probably occurred in Liguria only two to three centuries later than in Apulia, and almost contemporaneous with Sicily and Calabria (Biagi and Spataro 2001; Pessina and Tinè 2008, 39–41; Pearce 2013, 84). The rate of the spread of Neolithic technology along the Italian peninsula, over a distance of >1000 km, is possibly much faster than the rate suggested by the 'wave of advance' model (Ammerman and Cavalli Sforza 1984).

Direct evidence for processing of plant remains has been recovered from Arene Candide (quern stones and sickle blades), as well as the cave sites Arma di Nasino, Arma dello Stefanin and Grotta Pertusello. These records indicate cultivation of *Triticum* spp. and *Hordeum* spp., and *Lens culinaris* and *Vicia* (Nisbet 2006). Charcoal records attest to the exploitation of woodland, especially *Quercus pubescens*, *Q. ilex*, *Acer*, *Fraxinus*, *Ulmus*, *Fagus* and *Pinus*. For example, at Arene Candide, a wide variety of woodland was utilised by the occupants of the cave, including deciduous *Quercus*, *Quercus ilex*, *Pistacia*, *Phillyrea*, *Olea*, *Pinus*, *Taxus*, *Acer*, *Erica arborea*, *Arbutus unedo* and *Ulmus* (Nisbet 1997). The low concentration of charcoal and high taxa diversity indicates low-intensity occupation, which did not have a significant impact on the vegetation cover (Fig. 3). Supporting this interpretation is the land snail assemblage, which indicates low levels of disturbance and a

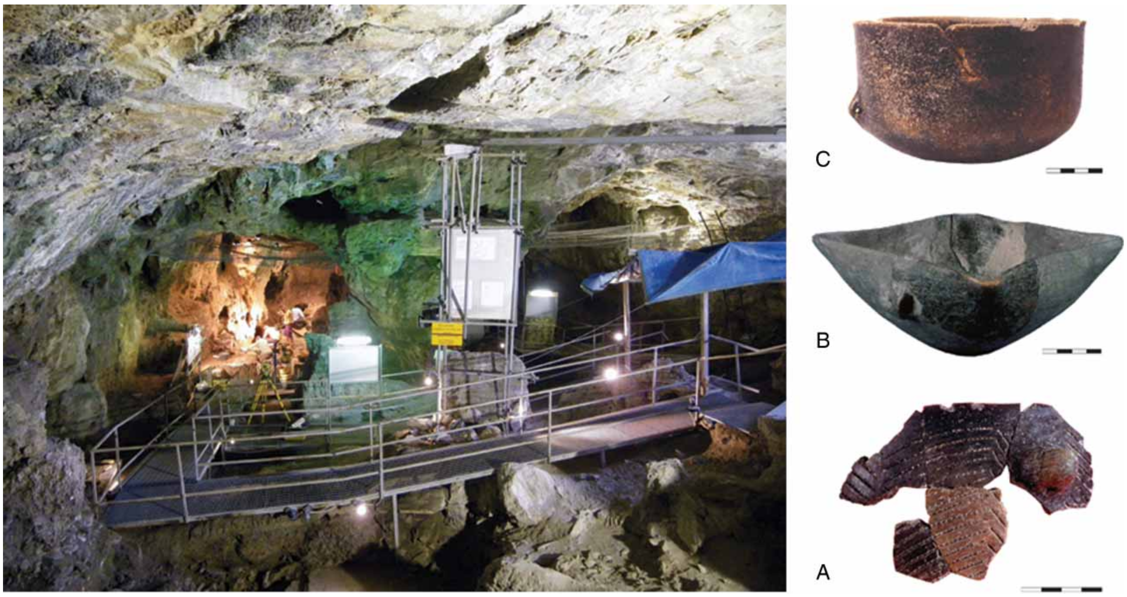

Figure 2 Arene Candide cave, and (A) Impressa pottery, (B) Square Mouthed pottery, and (C) Chassey pottery.

diverse range of habitats including damp and dry ground, and woodland (Fig. 3; Girod 1997).

The zooarchaeological remains from Arene Candide indicate the introduction of domesticated sheep, as well as ibex hunting, with sheep exploited for milk and meat (Fig. 3; Rowley-Conwy 1997), while the pollen and geoarchaeological evidence indicates stabling of animals (Fig. 4; Branch 1997; Macphail *et al*. 1997). The presence of several sites some distance from the coast in the Pennavaira valley (~20 km inland) and situated up to at least 800 m asl provide an important insight into resource exploitation and possible environmental impact over a wide spatial area. For example, archaeological evidence from the cave of Arma dello Stefanin suggests that the colonisation of inland areas had already commenced by ~7500 cal yrs BP (Barker *et al*. 1990), while Leale Anfossi (1953) reported the discovery of *'Impressa Ligure'* sherds at the upland cave of Le Camere.

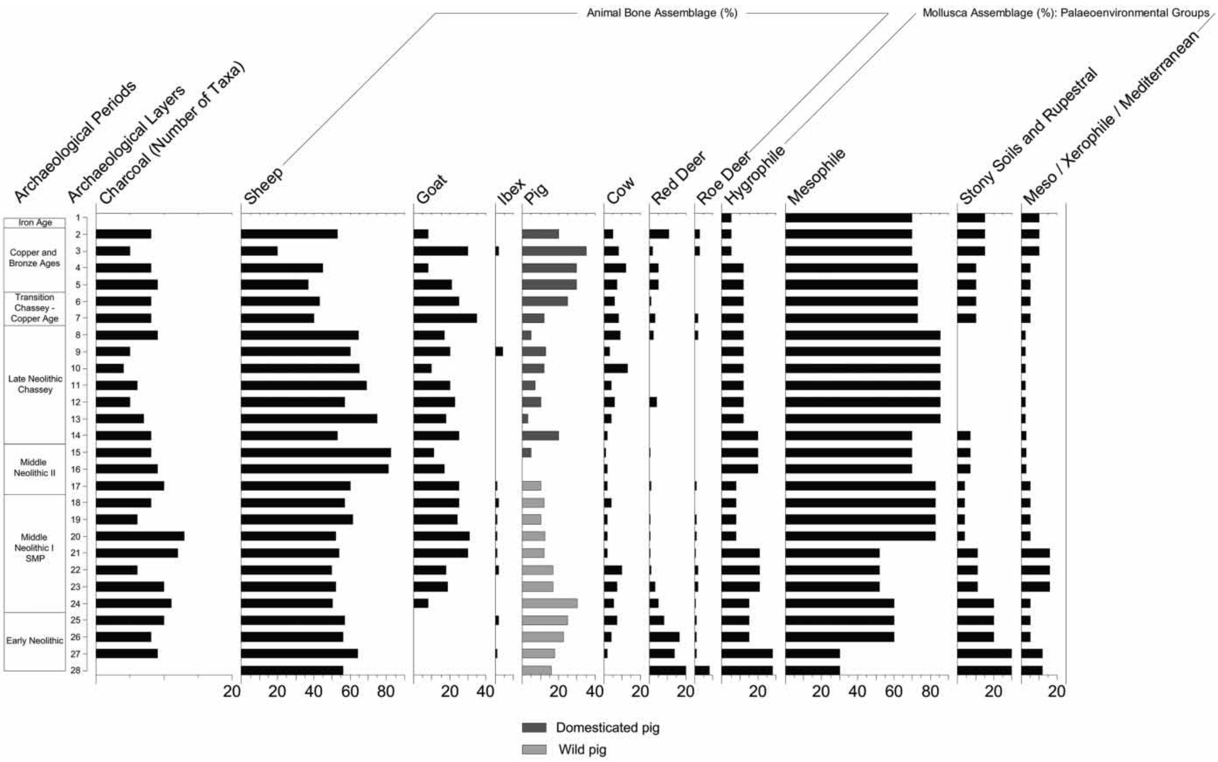

Figure 3 Charcoal (Nisbet 1997), animal bone (Rowley-Conwy 1997) and Mollusca (Girod 1997) environmental archaeological data from Arene Candide.

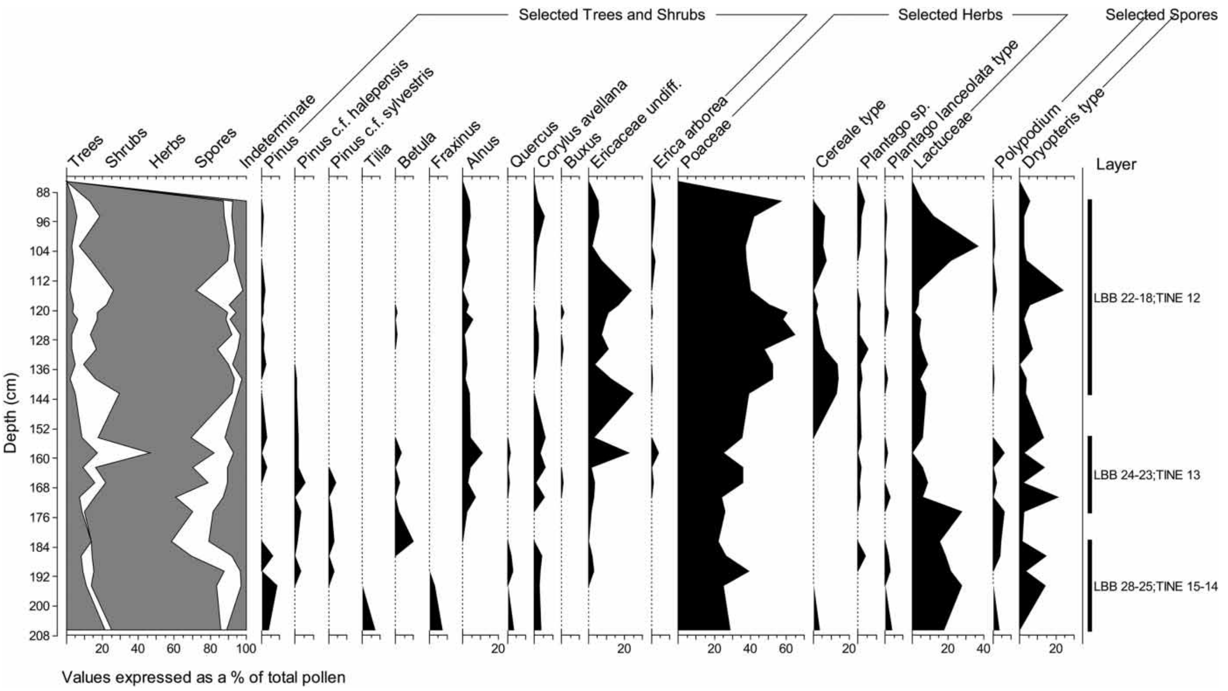

Figure 4 Selected taxa pollen diagram from Arene Candide (location 12; adapted from Branch 1997); LBB 28-25/Tinè 15-14 = Early Neolithic; LBB 24-23/Tinè 13 = beginning of the Middle Neolithic; LBB 22-18/Tinè 12 = Middle Neolithic.

The evidence therefore indicates that the Early Neolithic settlers of western Liguria were sea travellers and 'pioneer colonists', bringing a wealth of knowledge about farming and pottery production, as well as new 'raw materials' such as obsidian, and domesticated plants and animals (Maggi 1997a, 1999, 2004). Indeed, the Early Neolithic *'Ceramica Impressa Ligure'* culture of western Liguria and Provence is widely regarded as being part of a larger complex of the Impressed Ware Pottery Culture that spread generally east-west along the north-west Mediterranean coast during the 8th millennium BP (Zilhão 2003).

In eastern Liguria, the archaeological evidence for the Early Neolithic is quite different. The main site is at Pianaccia di Suvero (Maggi 1983; Biagi *et al.* 1987), which has archaeological evidence very different to sites in the west. It is an open-air site located on a terrace at mid-altitude (600 m asl), 18 km from the coast. Although the site lacks Neolithic stratigraphy due to erosion, some aspects of the stone tool assemblage, such as the shape of numerous cores, the abundance of narrow regular bladelets, the ipermicrolithism of several end scrapers and points, and the raw material (mainly red radiolarite), suggest possible linkages between the chipped stone industry and the Late Mesolithic Castelnovian culture (Martino *et al.* forthcoming). This suggests that the site may represent the acculturation of the local Mesolithic population (Maggi forthcoming), although the recent comprehensive work by Franco (2011) may rule out this possibility. The age of the site is consistent with radiocarbon dated records from northern Tuscany that belong to the Pianaccia di Suvero group, such as Muraccio and Pian di Cerreto, that span from 7670–7430 (Rome-548) to 7290–6890 (Rome-427) cal yrs BP (Ferrari and Steffè 2006, 89). The Neolithisation of Liguria may therefore have followed two routes: arrival of maritime pioneers in the west, and acculturation of local Mesolithic populations in the east. However, the latter hypothesis requires rigorous testing with new archaeological and chronological data from eastern Liguria.

Middle Neolithic (Square Mouthed Pottery Culture)

Shortly before ~7000 cal yrs BP, the introduction of a new pottery style of the 'Vhò' and 'Fiorano' groups of the Po plain (Biagi 1987; Tinè 1999b), flint from the Alpine region (Starnini and Voytek 1997a) and domesticated goats (Rowley-Conwy 1997) characterised the end of the Impressed Ware Pottery Culture (Figs. 1 and 2B). The integration of 'new' knowledge from the Po plain with existing cultural traditions, coupled with increased population pressure in coastal areas, probably acted as a catalyst to the development of a new culture of the Middle Neolithic: the Square Mouthed Pottery Culture, with increased capacity for the more intensive exploitation of the Ligurian environment and its resources. The Middle Neolithic was epitomised by the unusual shape of some of the pottery, which spread over northern Italy at this time (Bernabò Brea 1956; Bagolini 1990; Barfield *et al.* 2003; Bernabò Brea *et al.* in press).

The adoption of new techniques, such as 'shredding' for leaf fodder (Maggi and Nisbet 2000; Arobba and

Caramiello 2010; Arobba *et al.* in press), and the occupation of all available caves, suggests the presence of a well-developed economy based primarily on animal husbandry. At Arene Candide, during the first two centuries (Square Mouthed Pottery 1), animals were stabled in the cave, probably throughout the year (Fig. 3; Rowley-Conwy 1997), with fodder collected nearby. The complimentary geoarchaeological and bioarchaeological data indicate grazing outside the cave in a range of habitats, and the utilisation of bedding materials for animals, especially straw and grass, and animal fodder comprising leaf hay (Figs. 3 and 4; Branch 1997; Girod 1997; Macphail *et al.* 1997). Both sheep and goats were important to the economy and the evidence from Arene Candide indicates a mainly meat-based strategy at this time (Fig. 3; Rowley-Conwy 1997). The presence of wood working tools (Starnini and Voytek 1997a, 1997b; Ballara 2002) and anatomical evidence from wood charcoal and phytoliths (Macphail *et al.* 1997; Nisbet 1997; Maggi and Nisbet 2000; Arobba pers comm) that are consistent with woodland management, suggest that the cave occupants recovered significant and regular quantities of leaf fodder.

The charcoal records from Arene Candide do point, therefore, to a discernable impact on the vegetation cover during the Middle Neolithic, probably due to a more complex system of woodland management. The amount of charcoal increases significantly, suggesting a change in the nature of human activities inside and outside the cave (Fig. 3). During the early part of the Middle Neolithic, several taxa not utilised during the Early Neolithic are present, including *Corylus*, *Ostrya* and *Prunus*, while others are not present, especially *Olea*, *Taxus* and *Arbutus unedo*. However, many of the taxa present during the Early Neolithic continue to be exploited and it is not until the latter part of the Middle Neolithic that there appears to be an overall reduction in species diversity. Once again, this is consistent with the land snail assemblage, which indicates a reduction in woodland, and a predominance of moderate–to-dry environmental ranges for the taxa (Fig. 3; Girod 1997).

The evidence for cereal cultivation during the Middle Neolithic is sparse in Liguria but records from Arene Candide, Sanguineto, Bergeggi, Pian Ciliegio and Riparo due Teste indicate that *Hordeum*, *Triticum dicoccum*, *Triticum aestivum* and *Triticum compactum* were grown by the occupants of these caves, who also consumed *Vitis vinifera* (Branch 1997; Arobba and Caramiello, 2006, 2009, in press). That cereals were probably cultivated near to the caves is confirmed by the record of spikelets of *T. dicoccum* at Arene Candide. As Arobba *et al.* highlight, however, 'In Liguria, the rarity of sites with paleo-ethnobotanical evidence and their specialized location probably distorts the paleoagrarian picture altogether' (1997, 122).

Late Neolithic (Chassey Culture)

At Arene Candide, in the strata dated to ~6150 cal yrs BP, 50% of the stone tools are made of honey-coloured good quality 'Bedoulien' flint from Vaucluse (south-east France), which was commonly used by the Chassey Culture of southern France (Starnini and Voytek 1997a, 379, 382). The *'Chasséen Meridional'* is also the typology of both flint and pottery artefacts (Figs. 1 and 2C). The changes in the material culture accompany a sudden increase in the size of domesticated sheep (Rowley-Conwy 1997), and the stratigraphy becomes a series of superimposed layers of manure mixed with urine that was burnt to form discreet, undisturbed layers of white ash (Macphail *et al.* 1997).

The apparent impact on woodland cover during the latter stages of the Middle Neolithic became intensified during the Late Neolithic with a significant reduction in species diversity (Fig. 3) and especially previously dominant taxa, such as *Quercus ilex* (see Nisbet 1997). Nisbet highlights the 'almost complete disappearance of the broadleaved trees' (1997, 108), which is attributed to possible leaf foddering. This record of human impact on the environment in western Liguria is particularly evident during the latter stages of the Late Neolithic when a reduction in deciduous *Quercus* has been linked to the local formation of 'Mediterranean macchia' dominated by *Quercus ilex*, *Arbutus unedo*, *Erica arborea*, *Rhamnus alaternus*, *Phillyrea*, *Olea* and *Pistacia lentiscus* (Girod 1997; Nisbet 1997).

The zooarchaeological evidence indicates the introduction of domesticated pig (Rowley-Conwy 1997, 2012), and overall the data imply a greater emphasis on the herding of sheep, goats, cows and pigs than on plant cultivation (Fig. 3); the site distribution pattern indicates that this system included short-distance transhumant pastoralism between the coast and inland. Tana del Barletta (1000 m asl), for example, has provided zooarchaeological evidence for 54·2% sheep/goat, 21·9% cattle and 20·8% pig (Barker *et al.* 1990). Charcoal records indicate woodland exploitation of *Quercus pubescens*, *Prunus*, *Acer* and *Cornus*. The cave was probably a camp linking the primary zone of permanent settlement on the coastal lowlands with summer grazing land in the uplands. Significantly, it highlights the emergence of transhumant pastoralism with the onset of the Chassey culture in western Liguria (Maggi and Nisbet 1990).

In eastern Liguria, once again there is a paucity of Late Neolithic archaeological sites, beside pottery sherds and settlement evidence from Genoa (Del

Lucchese 2010), there are only a few Chassey-like pottery fragments from Castellaro di Uscio (Maggi and Vignolo 1990, 148), and Tana delle Fate (Maggi and Vignolo 1984; Cocchi Genick 2012, 249–250). The latter is just a few kilometres from the prehistoric copper mines of Libiola and Monte Loreto (Maggi and Pearce 2005) and the large radiolarite quarry of Valle Lagorara (Campana and Maggi 2002). A copper awl, found in the Chassey layers at Arene Candide, is similar to others found in Late Neolithic contexts in Italy (Campana and Franceschi 1997; Pearce 2000; Maggi and Campana 2008). Their chronology is close to the beginning of mining at Monte Loreto at 5890–5650 cal yrs BP (Beta-203528), at the Late Neolithic-Copper Age transition (Maggi and Pearce 2005, 2013; Maggi et al. 2011). This suggests that the Late Neolithic introduction and widespread expansion of a pastoral-based economy allowed the development of a social organisation that suddenly became able to adopt new, heavy technologies, such as managing mines and quarries.

Synthesis of the Palaeoenvironmental Records

Chronology of the Palaeoecological Records from Liguria

Table 1 presents the calibrated radiocarbon dates from key palaeoecological records spanning the Neolithic in Liguria (Branch 2002, 2004, 2013; Bellini *et al.* 2009; Cruise *et al.* 2009; Guido *et al.* 2013). Despite the small number of dates and absence of $\delta^{13}C$ (‰) values from some sites, and overall concern about the quality of materials dated, the start (~7800 cal yrs BP) and end (~5700 cal yrs BP) of the Neolithic can be broadly determined at each site. This has enabled reconstruction of the key vegetation changes, and evaluation of the relative influence of human activities and climate change, across a wide altitudinal range. There is a clear need, however, to improve the chronological framework for the Neolithic, which will enable the creation of new age models (see Cruise *et al.* 2009; Branch 2013) and hence improve understanding of the timing and duration of Neolithic human activities. Furthermore, there is clearly a geographical bias in the palaeoecological records to eastern Liguria, and there is an urgent need to discover and analyse suitable sites in western Liguria where there is the highest concentration of known Neolithic archaeological sites (see above). These issues will form the primary focus of future research.

Vegetation History

Several key palaeoecological studies in eastern Liguria have provided an opportunity to consider the nature and impact of human activities during the Neolithic across a wide altitudinal range (Braggio Morucchio *et al.* 1988; Cruise 1990; Branch 2002, 2004, 2013; Bellini *et al.* 2009; Cruise *et al.* 2009; Guido *et al.* 2013). At low altitude, a pollen record from Sestri Levante (<100 m asl) indicates that from 8180–7930 cal yrs BP to sometime after 6850–6560 cal yrs BP, *Abies* and *Corylus* initially dominated the woodland cover, succeeded by deciduous *Quercus*, *Quercus ilex* and *Erica arborea* (Fig. 1; Table 1; Bellini *et al.* 2009). The colonisation of the tree-heath community during the Early Neolithic, which is more typical of dry, coastal Mediterranean habitats today, may have occurred as a response to human activity, including deliberate burning and pastoralism. The record indicates the presence of several ruderal taxa that are associated with pastoralism, notably Apiaceae, Asteraceae, *Artemisia*, Lactuceae, Brassicaceae, Fabaceae, *Plantago*, *Rumex* and *Urtica* (see Mercuri *et al.* 2010; Rius *et al.* 2012). Supporting this interpretation is the evidence for cereal cultivation in the pollen record, although there remains a possibility these are pollen grains of wild Mediterranean grasses (see Mercuri 2008). Nevertheless, the record of cereal plant macrofossils in a wetland context from nearby Chiavari (Ottomano 2004), does suggest that during the Early and Middle Neolithic human activities in eastern Liguria were perhaps having a widespread impact at low altitude, which is consistent with the records from western Liguria.

Similarly, at Rapallo (<100 m asl; Fig. 1), Bellini *et al.* (2009) provide an important record of vegetation succession from the Late Mesolithic/Early Neolithic transition through to the Copper Age (8060–7930 to 5330–5040 cal yrs BP; Table 1). The Early Neolithic was dominated by *Abies* with mixed deciduous woodland and shrubland including *Ulmus* and *Tilia*, and deciduous *Quercus* and *Corylus.* The presence of *Quercus ilex*, *Pinus* and *Erica arborea* once again suggests that elements of the tree-heath community were established here by the Early Neolithic. The sporadic occurrences of cereal pollen, together with the range of ruderal taxa noted for Sestri Levante, confirm the possible presence of human activities in Rapallo at this time, which seemingly included cultivation and pastoralism. At ~7000 cal yrs BP, *Abies* woodland declined at Rapallo and Sestri Levante; this coincided with an increase in biomass burning, shrubland (*Corylus*) and ruderal taxa (e.g. *Rumex*), as well as deciduous *Quercus* and *Quercus ilex*. This trend continued into the Late Neolithic and early Copper Age, accompanied by cereal pollen throughout the sequence (Bellini *et al.* 2009). Combined, the palaeoecological evidence indicates that human activities in the coastal zone of eastern Liguria were having an affect on the environment during the Neolithic, which included burning, cereal cultivation and animal husbandry.

Table 1 Radiocarbon dates from key palaeoecological records (mentioned in the text) in Liguria*

Site	Location	Elevation (m asl)	Author(s)	Depth (cm)	Laboratory code	Uncalibrated yrs BP (conventional age)	Cal yrs BP (95·4%)	$\delta^{13}C$ (‰)	Material
Lago Rotondo	44°29′27″N 9°25′2″E	1331	Branch (2004)	487–494	Beta-106143	6410 ± 60	7434–7180	−24·8	Wood (*Fagus*)
				603–613	Beta-106144	7100 ± 80	8154–7730	−27·4	Peat
Lago Riane	44°32′50″N 9°28′40″E	1279	Branch (2013)	120–130	Wk-20141	1647 ± 43	1691–1414	−27·4	Peat
				445–455	Wk-20142	4081 ± 47	4815–4436	−29·7	Peat
				590–600	Wk-20143	4795 ± 49	5609–5329	−28·8	Peat
				690–700	Beta-106141	5280 ± 80	6275–5911	−30·4	Peat
				815–825	Wk-20144	8078 ± 50	9235–8771	−31·3	Peat
				840–850	Wk-20145	8707 ± 56	9888–9545	−32·4	Peat
				865–875	Beta-106142	9070 ± 70	10,485–9939	−30·0	Peat
Mogge di Ertola	44°32′56″N 9°21′51″E	1115	Guido *et al.* (2013) Cevasco *et al.* (2013)	50	LTL-546A	1065 ± 80	1180–790	−29·3 ± 0·3	Peat
				80	LTL-2970A	1982 ± 40	2010–1820	−23·9 ± 0·4	Peat
				135	LTL-2971A	3336 ± 40	3650–3460	−25·3 ± 0·3	Peat
				335	LTL-1220A	7190 ± 60	8170–7930	−25·8 ± 0·5	Peat
				445	LTL-2972A	8156 ± 50	9270–9000	−27·1 ± 0·3	Peat
				615	LTL-2973A	9061 ± 60	10,410–10,140	Unknown	Peat
				630	LTL-547A	8912 ± 100	10,250–9650	−30·1 ± 0·2	Peat
Lago di Bargone	44°17′N 9°29′E	831	Cruise *et al.* (2009)	Bg89: 85–95	SRR-3813	2375 ± 45	2690–2330	Unknown	Peat
				Bg89: 175–185	SRR-3814	4625 ± 50	5580–5080	Unknown	Peat
				Bg89: 235–245	SRR-3815	6075 ± 45	7160–6790	Unknown	Peat
				Bg89: 423–433	SRR-3816	10 690 ± 450	13,460–11,230	Unknown	Silty Peat
				Barg 94: 130–132	GrN-21308	700 ± 60	740–550	Unknown	Peat
				Barg 94: 203–205	GrN-21305	5390 ± 60	6300–5990	Unknown	Peat
				Barg 94: 250–252	GrN-21306	8390 ± 110	9550–9090	Unknown	Peat
				Barg 94: 300–303	GrN-21307	10 870 ± 90	12,960–12,780	Unknown	Silty Peat
Rovegno	44°34′33″N 9°17′12″E	812	Branch (2004)	116–125	Beta-106212	4380	5213–4850	−28·8	Peat
				240–243	Beta-104794	11,690	13,637–13,432	−27·5	Peat
Lagorara	44°21′N 9°31′E	776	Branch (2002)	Context 11	GrA-5145	5010 ± 50	5880–5660	Unknown	Organic sediment
				Context 11	GrA-5113	5380 ± 70	6281–6024	Unknown	Organic sediment
				Context 12	GrA-5180	6360 ± 60	7415–7248	Unknown	Organic sediment
				Context 12	GLN-21807	6730 ± 50	7656–7567	Unknown	Organic sediment
Sestri Levante	44°16′N 9°24′E	Unknown	Bellini *et al.* (2009)	S3: 1420	Unknown	5894 ± 45	6850–6560	Unknown	Wood
				S4: 1800	Unknown	5161 ± 60	6180–6560	Unknown	Wood
				S4: 2490	Unknown	7213 ± 65	8180–7930	Unknown	Wood
Rapallo	44°21′N 9°13′E	Unknown	Bellini *et al.* (2009)	910	Unknown	4563 ± 50	5330–5040	Unknown	Charcoal
				1660	Unknown	7175 ± 45	8060–7930	Unknown	Charcoal

*For calibration and software details, and approaches to reporting radiocarbon dates, see Stuiver and Polach 1977; Stuiver and Reimer 1986; Bronk Ramsey, 1995, 1998, 2001, 2009; Reimer *et al.* (2004).

The importance of *Abies* woodland during the Early Neolithic has been highlighted by a number of other studies in lowland areas of Liguria (Montanari *et al.* 1998; Arobba *et al.* 2001). At mid-altitudes (up to 1000 m asl), *Abies* appears to have been equally important. At Lago di Bargone (831 m asl; Fig. 1; Table 1), *Abies* was dominant throughout the Late Würm Lateglacial and Early Holocene, but its decline at ~7800 cal yrs BP, along with *Pinus*, *Ulmus* and *Tilia*, led to an expansion of deciduous *Quercus* woodland (Cruise *et al.* 2009). Accompanying this transition was an increase in light demanding taxa, notably *Corylus*, Ericaceae and *Pteridium*, and infrequent occurrences of possible cereal pollen suggesting either localised cultivation or the transportation of pollen from lower altitudes by animals. Throughout the Neolithic the persistence of cereal pollen and ruderal taxa, notably Asteraceae, *Chenopodium* type, *Artemisia*, Caryophyllaceae, Lactuceae, *Plantago lanceolata* and *Melampyrum,* suggests the continued presence of pastoralism and possible cultivation. The decline of *Abies* woodland at ~7800 cal yrs BP appears to be earlier than reported for the coastal zone, although improvement is required in the chronology of the sites at Rapallo and Sestri Levante to test this hypothesis.

In contrast, at Rovegno (812 m asl; Fig. 1; Table 1) the Early Neolithic was characterised by fluctuating *Abies* woodland, a marked decline in *Tilia* and *Ulmus*, and a corresponding increase in grassland and herbaceous taxa (Branch 2004). Deciduous *Quercus* expanded from the Middle Neolithic onwards (~7000 cal yrs BP) together with *Corylus*, which resulted in a sustained decline in *Abies.* Similar to Lago di Bargone, a significant increase in *Pteridium* at this time is especially important and suggests a more open woodland structure, possibly accompanied by burning. Accompanying this was a small increase in ruderal taxa, notably *Sinapis* type and Caryophyllaceae. Pollen analysis of a buried soil sequence at Lagorara (920 m asl; Fig. 1; Table 1) confirms, however, that there was marked variation in composition and structure of woodland at this altitude in Liguria during the Neolithic, which may relate to a number of factors including natural competition and migration rates, climate change and levels of human activity. The results from Lagorara revealed that by ~7600 cal yrs BP, *Fagus* and *Abies* woodland had become co-dominant in the Lagorara Valley with only minor amounts of deciduous *Quercus.* Similar to the other studies, however, there was a pronounced decline in *Ulmus* and *Tilia* woodland, as well as *Corylus* shrubland, during the Early Neolithic (Branch 2002).

At higher altitude (>1000 m asl), pollen records from Lago Riane (Figs. 1 and 5; Branch 2013) and Lago Rotondo (Branch 2004) indicate that *Abies* dominated the vegetation cover forming mixed coniferous-deciduous woodland with deciduous *Quercus*, *Tilia, Ulmus* and *Corylus* during the Early Neolithic (Table 1). Although percentages of non-arboreal pollen (NAP) are 15–20% (of total land pollen), the palaeoecological evidence for human activity remains uncertain with few of the ruderal pollen taxa

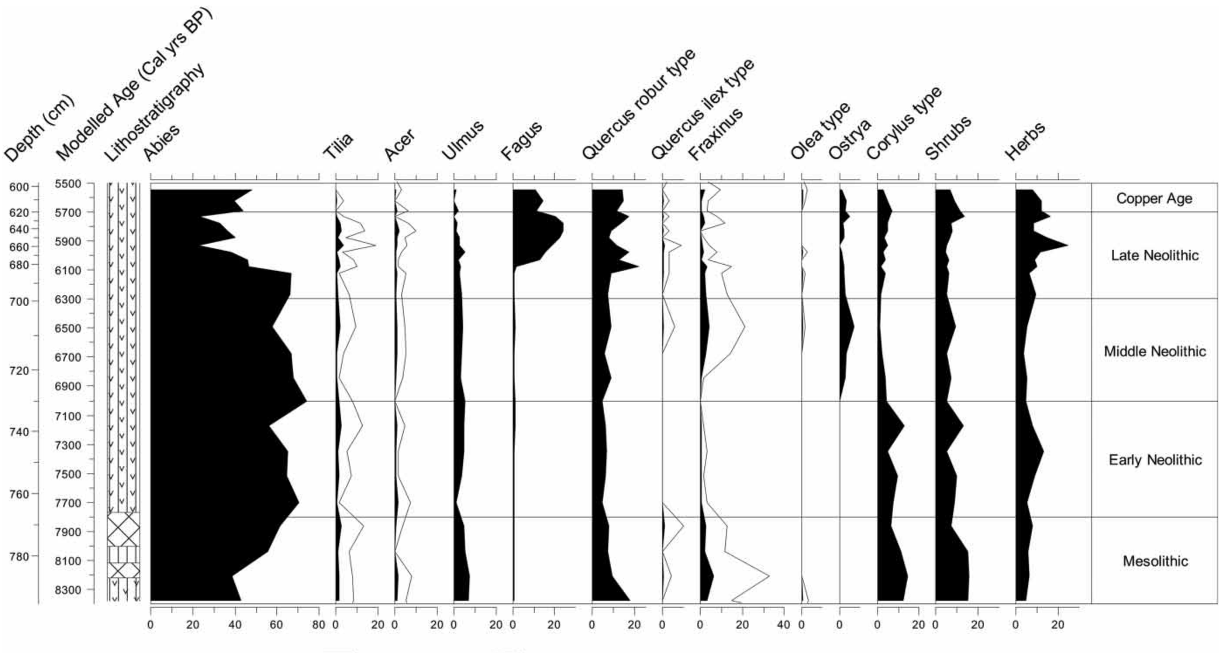

Figure 5 Selected taxa pollen diagram from Lago Riane (44°32′50″N 9°28′40″E; 1279 m); the diagram has been 'zoned' according to the main cultural periods (see Branch 2013 for the full pollen diagram and modelled radiocarbon dates).

associated with pastoralism present in significant quantities. The transition to the Middle Neolithic (~7000 cal yrs BP) was marked by a sustained reduction in *Abies* and expansion of *Fagus* woodland at Lago Rotondo, but only a temporary decline in *Abies* at Lago Riane (Fig. 5). In contrast, at Mogge di Ertola (Guido *et al*. 2013; Table 1) there was a significant, temporary reduction in *Abies* woodland during the Late Mesolithic/Early Neolithic (from ~8100 cal yrs BP) accompanied by evidence for burning, and an increase in herbaceous taxa and the expansion of *Fagus* and *Corylus* woodland. Although it is uncertain whether this event was associated with human interference, climate change or both, the record indicates that *Abies* subsequently re-established its dominance for the remainder of the Neolithic.

At Lago Riane, the Middle Neolithic and early part of the Late Neolithic recorded an increase in light loving taxa, such as *Fraxinus* and *Ostrya*, and a slight reduction in *Ulmus* woodland (Fig. 5). The change in woodland composition and structure probably facilitated the deposition of regionally dispersed pollen from lower elevations, such as *Olea* and *Quercus ilex*. This episode culminated in the expansion of *Fagus* woodland at ~6100 cal yrs BP, during the Late Neolithic, and the beginning of a sustained decline in *Abies* (Fig. 5). Both Lago Rotondo and Lago Riane indicate that the invasion of *Fagus* from the Middle Neolithic onwards coincided with increases in deciduous *Quercus* woodland and *Corylus* shrubland, and ruderal taxa, especially Apiaceae, *Rumex*, *Artemisia*, *Cirsium* and *Plantago lanceolata*. A reduction in *Tilia*, *Ulmus* and *Fraxinus* woodland commonly accompanied the *Fagus* rise, indicating a widespread change during the Neolithic in the woodland composition, which was probably associated with pastoralism at high altitudes in eastern Liguria.

The cause of the *Fagus* expansion during the Middle and Late Neolithic at high altitude is a matter of considerable debate, especially given the evidence for spatial variations in the nature and timing of the transition throughout northern and central Italy. The evidence for a reduction in deciduous woodland taxa, and a rise in shrub and ruderal taxa, has led to the suggestion that human activity was the primary cause, although alternative scenarios include climate change, and migration/successional rates and competition (Peltier et al. 1997; Magri et al. 2006; Magri 2007; Branch 2013; Guido et al. 2013). Indeed the strong association between the exploitation of *Ulmus* and *Tilia*, as well as *Abies* and *Fraxinus*, and leaf and branch foddering suggests that animal husbandry in eastern Liguria may have led to the decline of specific taxa, and the adventitious increase in *Fagus* through a reduction in competition. If human impact on the environment at higher altitudes from the Middle Neolithic was indeed the primary cause, then it emphasises the need to identify through survey and excavation further supporting archaeological data, which is frequently difficult because dense woodland cover, erosion and modern development pressures often obscure the evidence.

Climatic Context of Neolithisation in Liguria and the Central-western Mediterranean

There is a generally poor understanding of the relationship between climate change and cultural evolution during the Holocene in the central-western Mediterranean. This is despite recent improvements in our understanding of climate history (e.g. Yu and Harrison 1996; Ariztegui *et al*. 2000; Magny *et al*. 2002, 2003, 2007; Davis *et al*. 2003; Zanchetta *et al*. 2007; Roberts *et al*. 2008, 2011; Jalut *et al*. 2009; Peyron *et al*. 2011). This is in contrast to studies in the eastern Mediterranean where a clearer correlation between Neolithic communities and climate change has emerged (e.g. Moore and Hillman 1992; Harris 1996; Issar and Zohar 2004; Weninger *et al*. 2006; Berger and Guilaine 2009; Rambeau *et al*. 2011). Nevertheless, multi-proxy records for climate change derived mainly from pollen, stable isotopes and lake levels suggest that prior to the start of the Neolithic in Liguria, conditions were generally characterised by warm, wet winters, and warm, dry summers (e.g. Magny *et al*. 2007; Jalut *et al*. 2009; Peyron *et al*. 2011). They suggest the formation of typically supra-Mediterranean conditions during the Mesolithic in central and western parts of the Mediterranean, which coincided with the deposition of Sapropel S_1 from $10{,}800 \pm 400$ to 6100 ± 500 cal yrs BP in the eastern Mediterranean (Fig. 6; Myers and Rohling 2000; De Lange *et al*. 2008).

After 7800 cal yrs BP, Peyron *et al*. (2011) suggest that the warm, wet winters continued until ~5000 cal yrs BP, but the region experienced progressively lower rainfall levels in winter, and enhanced summer precipitation (Fig. 6). Therefore, the onset of the Neolithic in Liguria occurred during a period of climate change with a trend towards increasing aridification. Jalut *et al*. (2009) argue, however, that this period of climate change did not commence in the central Mediterranean until ~7000 cal yrs BP, which are supported by some palaeohydrological records (Magny *et al*. 2002). Records also indicate summer cooling from 7700 cal yrs BP (Peyron *et al*. 2011), which suggests that summers were characterised throughout the Neolithic by wetter, cooler conditions. According to Brewer *et al*. (2009), cooling during the winter and summer during this period shortened the length of the growing season in the western Mediterranean, and resulted in marked vegetation changes.

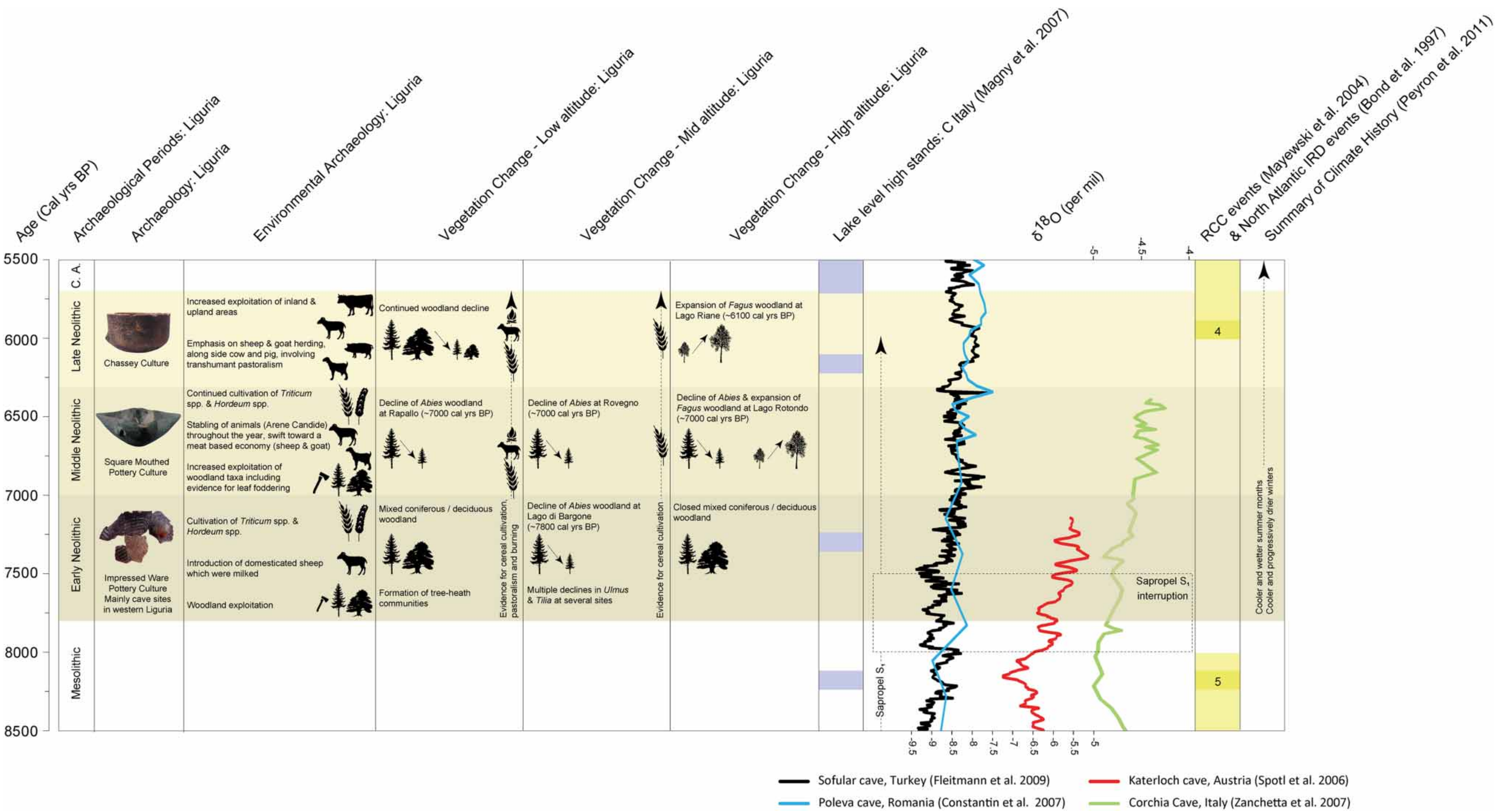

Figure 6 Summary of Neolithic archaeological, environmental and palaeovegetation records from Liguria (see text for details), and key palaeoclimatic records from the Mediterranean and Europe (see Bond *et al*. 1997; Mayewski *et al*. 2004; Spotl *et al*. 2006; Constantin *et al*. 2007; Magny *et al*. 2007; Zanchetta *et al*. 2007; Fleitmann *et al*. 2009; Peyron *et al*. 2011); animal profiles from M. Coutureau/C. Carpentier (© 2013 ArchéoZoo.org).

Fig. 6 also shows $\delta^{18}O$ values measured on stalagmite calcite from four locations in the Mediterranean and Western Europe (Spotl *et al.* 2006; Constantin *et al.* 2007; Zanchetta *et al.* 2007; Fleitmann *et al.* 2009). In these records, there is a general trend of less negative $\delta^{18}O$ values throughout the Neolithic period, which supports speleothem data from other parts of the Mediterranean, and suggests a transition from an Early Holocene wet phase to a cooler, drier climate (e.g. Bar-Matthews *et al.* 2000; Frisia *et al.* 2006; Zhornyak *et al.* 2011). Despite the evidence for climate change, therefore, from a range of archives and proxies, its impact on Neolithic communities in Liguria remains uncertain. It is worth noting, however, that the shorter growing season and wetter summers may have contributed to an intensification of farming from the Middle Neolithic as a response to climate change and to mitigate the risk of agricultural collapse (see also Mercuri *et al.* 2011). In addition, the termination of Sapropel S_1 may have coincided with the start of the Late Neolithic period in Liguria, although opinions vary on the precise timing of this event (De Lange *et al.* 2008). If correct, the Late Neolithic was possibly marked by a period of cooler, drier climate (see Bond *et al.* 1997; Ariztegui *et al.* 2000; Mayewski *et al.* 2004).

Discussion

The review of the environmental archaeological data from western Liguria has revealed that the initiation of farming during the Early Neolithic (~7800 cal yrs BP) appears to have been an abrupt event and formed part of the widespread Neolithisation of the western Mediterranean. Like many parts of Italy, the process was characterised by the introduction of new technology alongside domesticated plants and animals, and the exploitation of resources over a wide spatial area (coastal and inland), including altitudes up to 800 m asl from ~7500 cal yrs BP (see Barker 1985, 2006). During the Middle (~7000–6300 cal yrs BP) and Late Neolithic (~6300–5700 cal yrs BP), the evidence indicates that human activities became more intensive and more extensive, resulting in the exploitation of resources over a wider altitudinal range, and included animal husbandry (sheep, goats, cattle and pigs), transhumant pastoralism, woodland management and leaf foddering, and crop cultivation (Fig. 6).

Owing to the absence of environmental archaeological records spanning the Neolithic in eastern Liguria, evaluation of palaeoecological data from lakes and mires suggests that human activities, probably involving some or all of the practices recorded in western Liguria, had an impact on the landscape and environment from the Early Neolithic, initially at low to mid altitudes. The colonisation of tree heath communities (macchia) and deciduous and evergreen *Quercus*, and an increase in ruderal taxa, appears to have been a direct response to animal husbandry and cultivation, and led to the decline of *Abies*, *Ulmus* and *Tilia* woodland (Fig. 6). These taxa probably declined as a response to woodland clearance for grazing land and cultivation, and the exploitation of tree fodder. In the absence of substantive, corroborating archaeological evidence, this interpretation remains tentative; nevertheless, we may hypothesise that by the Middle Neolithic human groups were seemingly managing the vegetation cover to ensure a sustainable food resource for themselves and their animals across Liguria.

It is widely acknowledged that *Abies*, *Ulmus* and *Tilia*, and other taxa including *Fraxinus, Quercus* and *Fagus*, were important food for wild and domesticated animals (e.g. see Nisbet 1997 – Arene Candide; Heuze *et al.* 2005). The use of saplings, mast, leaves and branches as fodder may account for their overall decline, or fluctuating values, in pollen records from eastern Liguria, while browsing and grazing animals would undoubtedly lead to an increase in grassland and ruderal taxa. Palaeoecological studies in neighbouring parts of Italy and Europe support a causal relationship between the decline of *Abies*, *Ulmus* and *Tilia*, and Neolithic animal husbandry and cereal cultivation (e.g. Tinner *et al.* 1999; Parker *et al.* 2002; Grant *et al.* 2011). For example, in the northern Apennines, the pollen record from Prato Spilla 'A' (Emilia-Romagna) indicates a marked decline in *Ulmus*, *Tilia* and *Fraxinus* at ~7000 cal yrs BP, which is interpreted as evidence for pastoralism during the Middle Neolithic at high altitude (labelled M1; Lowe *et al.* 1994a, 1994b). At Lago Padule and Lago Pratignano (Emilia-Romagna), a modest increase in ruderal taxa indicative of pastoralism accompanied the *Fagus* rise at ~7000 cal yrs BP, notably Caryophyllaceae, *Rumex*, *Sinapis* type and Apiaceae (Watson 1996). Evidence for burning, a decline in *Abies*, and expansion of *Fagus*, from ~7000–5000 cal yrs BP at Lago del Greppo (Emilia-Romagna) has also been linked to Neolithic human activity (Vescovi *et al.* 2010a). In the Italian Alps, Valsecchi *et al.* (2008) correlate the expansion of *Fagus* at Lago di Fimon (23 m asl) with the decline of *Ulmus*, *Tilia* and *Fraxinus* and a reduction in burning due to human activities from ~7300 to 6400 cal yrs BP.

Similarly at Lago dell'Accesa (Tuscany), a decline of *Quercus ilex* during the Early Neolithic (~7700 cal yrs BP), accompanied an increase in taxa indicative of Mediterranean macchia. The associated evidence for vegetation disturbance suggests that human activities were probably the main cause (Drescher-Schneider *et al.* 2007; Vannière *et al.* 2008; Colombaroli *et al.*

2008). Pollen records from Pisa and the Versilia Plain (Bellini *et al.* 2009) also indicate the expansion of deciduous *Quercus* and *Quercus ilex* following the decline of *Abies* woodland at ~7000 cal yrs BP, together with the occasional presence of cereal pollen and ruderal taxa (e.g. *Urtica*, *Rumex*), suggesting localised cultivation and pastoralism. As noted, although the pollen evidence for cereal cultivation from several lowland locations is a matter for debate, given the unequivocal archaeobotanical records from western Liguria, and other parts of Italy, for the growth of both *Hordeum* spp. and *Triticum* spp. it seems likely that such practices were widespread.

During the Late Neolithic, the onset (or continuation) of the *Abies* decline and the corresponding widespread expansion of *Fagus* woodland in eastern Liguria has been attributed to the influence of highland pastoralism, which is supported by the environmental archaeological records from western Liguria (Fig. 6; Branch 2013). Several palaeoecological studies in neighbouring areas support this interpretation. At Prato Spilla 'A', *Fagus* expanded at ~5800 cal yrs BP accompanied by a temporary decline in *Abies* and soil erosion (Lowe *et al.* 1994b), while at Pavullo (Emilia-Romagna), the decline of *Abies* at ~6000 cal yrs BP has also been linked to possible human activities resulting in the expansion of *Quercus*, *Fagus* and herbaceous taxa (Vescovi *et al.* 2010b). Similarly, at Lago di Massaciuccoli (Tuscany), the pollen record indicates a significant decline of *Abies* and *Quercus ilex* at ~6000 cal yrs BP (Colombaroli *et al.* 2007; Mariotti-Lippi *et al.* 2007). Evidence for burning and the subsequent expansion of fire-resistant taxa suggest human activity and/or climate change as possible causes. However, given the outstanding evidence at this time for human modification of the environment, which undoubtedly included *'fire management'*, it seems highly likely that the record from Lago di Massaciuccoli indicates human activities.

Alternative explanations for the changes in vegetation cover recorded in eastern Liguria, and in many other parts of central and northern Italy, during the Neolithic range from disease, migration rates and competition, natural burning events and climate change (e.g. van der Knapp *et al.* 2005; Magri *et al.* 2006; Wick and Möhl 2006; Branch 2013). As noted above, there is good evidence from neighbouring parts of Italy, and the Northern Hemisphere in general, for climate change during the Neolithic. Indeed, Sadori *et al.* state 'Overall, we can conclude that before c. 4000 yr BP the main cause of vegetation change in the central Mediterranean was climatic variations, even if locally human impact can be detected' (Sadori *et al.* 2011, 126; see also Finsinger *et al.* 2010). Broadly supporting this interpretation are other key palaeoenvironmental studies, notably at Lago di Mezzano [Lazio] (Ramrath *et al.* 2000), Lago di Vico [Lazio] (Magri and Sadori 1999) and Lago di Pergusa [Sicily] (Sadori and Narcisi 2001; Sadori *et al.* 2013). Certainly, prolonged winter frosts during cooler winters may have had a detrimental impact on climatically sensitive taxa such as *Abies*, and created optimal conditions for invasive taxa such as *Fagus* (see Huntley *et al.* 1989; Magri 2007). In addition, periods of increased summer aridity (e.g. at ~7600 and ~6200 cal yrs BP) are thought to have initiated episodes of burning (Vannière *et al.* 2008, 2011). Various studies have demonstrated that *Abies* is highly susceptible to localised extinction by fire, whereas *Ulmus*, *Tilia* and *Fraxinus* tend to sustain long-term damage by fire (rather than extinction), which might lead to their progressive decline (Tinner *et al.* 2000; Colombaroli *et al.* 2009). At Lago dell'Accesa, for example, the decline in *Quercus ilex* between ~8000 and ~7600 cal yrs BP was synchronous with an increase in burning and the expansion of taxa associated with human activities, notably *Plantago lanceolata*, *Rumex acetosella*, Lactuceae, Chenopodiaceae, *Apium*, *Artemisia* and *Pteridium*, which may be linked to Neolithic agricultural activities (Drescher-Schneider *et al.* 2007; Colombaroli *et al.* 2008). Similarly, the increase in *Pteridium* at Lago di Bargone and Rovegno during a period of woodland decline does suggest that localised fire may have been an important factor in eastern Liguria. Whether this evidence indicates human or naturally/climatically induced fire remains uncertain. However, the diachronous changes in vegetation cover and burning do suggest that human activities were probably the primary cause.

Conclusion

This integrated study of the environmental archaeological and palaeoenvironmental records for Liguria has enabled evaluation of timing, rate and nature of Neolithisation, and an assessment of human impact on the environment against a background of climate change. The evaluation has established that Neolithisation was a rapid process in the west, consistent with other parts of the Mediterranean, due to maritime colonists introducing familiar Neolithic traits, while in the less documented east acculturation of indigenous Mesolithic populations was also probably involved. Palaeoecological records spanning the Early Neolithic from eastern Liguria, supported by environmental archaeological evidence from the west, indicate that the impact on the environment was perhaps more extensive than previously thought (low and mid altitudes), and involved both cereal cultivation and pastoralism. In other parts of the northern Apennines, however, the evidence suggests that Early Neolithic human groups were causing environmental changes at high altitude.

During the Middle Neolithic, the environmental archaeological evidence indicates an intensification of human activities, primarily focussed on animal husbandry, and involving the management of woodland for leaf foddering. We have argued that these practices led to a reduction in woodland cover across a wide altitudinal range in both eastern and western Liguria, despite the evidence for climate change. There remains a possibility, however, that climate change may have stimulated the adoption of a more intensive farming system at this time. The Late Neolithic witnessed a significant transformation of the social, technological and economic organisation of Liguria. Palaeoecological data indicate further changes in woodland composition, accelerated erosion and an increase in ruderal taxa commensurate with the development of transhumant pastoralism. The archaeological records support this interpretation with evidence for an increase in sites over a wider altitudinal range in western Liguria.

Finally, it is apparent from the evaluation that to address in detail the Neolithisation of Liguria and neighbouring areas, we must make significant improvements to the chronological framework from both archaeological and geological archives. The routine application of additional dating methods, such as tephrochronology, will assist this process and will lead to refinements in our understanding of key cultural and environmental transitions. In addition, future research in Liguria will necessitate the development of independent palaeoclimatic models for the Holocene using stable isotope analysis of stalagmites (western Ligurian caves) and plant macrofossils (eastern Ligurian lakes and mires), which will enable improved assessment of the role of climate change in cultural evolution and vegetation succession. Furthermore, the paper has highlighted the urgent need for the study of lakes and mires in western Liguria to complement those in the east, and similarly the enhancement of the Neolithic archaeological record for eastern Liguria requires a long-term programme of survey and excavation.

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References

Abbate, E., Bettelli, G., Boccaletti, M., Bonazzi, U., Bortolotti, V., Braga, G., Cantalamessa, G., Casnedi, R., Centamore, E., Coli, M., Dallan Nardi, L., Decandia, F. A., Deiana, G., Elter, G., Fazzini, P., Forcella, F., Gasperi, G., Gelati, R., Gelmini, R., Giannini, E., Lazzarotto, A., Marchetti, G., Monteforti, B., Nardi, R., Pialli, G. P., Pieruccini, U., Plesi, G., Puccinelli, A., Raggi, G., Romano, A., Sandrelli, F., Verani, M. and Zanzucchi, G. 1982. *Carta Strutturale dell'Appennino Settentrionale 4, Scala 1:250,000*. Firenze: Consiglio Nazionale Delle Ricerche.

Ammerman, A. and Polglase, C. 1997. Analyses and descriptions of the obsidian collections from Arene Candide (with contribution from Alesssandra Cesana and Mario Terrani), pp. 573–92 in Maggi, R. (ed.), *Arene Candide: a Functional and Environmental Assessment of the Holocene Sequence*. Roma: Il Calamo.

Ammerman, A. J. and Cavalli-Sforza, L. L. 1984. *The Neolithic Transition and the Genetics of Populations in Europe*. New Jersey: Princeton University Press.

Ariztegui, D., Asioli, A., Lowe, J. J., Trincardi, F., Vigliotti, L., Tamburini, F., Chondrogianni, C., Accorsi, C. A., Bandini Mazzanti, M., Mercuri, A. M., van der Kaars, S., McKenzie, J. A. and Oldfield, F. 2000. Palaeoclimate and the formation of sapropel S1: inferences from Late Quaternary lacustrine and marine sequences in the central Mediterranean region. *Palaeogeography, Palaeoclimatology, Palaeoecology* **158**, 215–40.

Arobba, D. and Caramiello, R. 2006. Rilievo e studio di impronte vegetali da materiali archeologici. *Informatore botanico italiano* **38**(1), 9–13.

Arobba, D. and Caramiello, R. 2009. Indagini archeobotaniche sul deposito neolitico del Riparo di Pian Ciliegio, pp. 117–30 in Del Lucchese, A. (ed.), *Il Riparo di Pian Ciliegio*. Quaderni del Museo Archeologico del Finale 5. Finale Ligure (SV): Istituto Internazionale di Studi Liguri.

Arobba, D. and Caramiello, R. 2010. Evidenze di scalvatura in rami di frassino del Neolitico Medio, pp. 13–4 in Del Lucchese, A. and Melli, P. (eds.), *Archeologia Metropolitana, Piazza Brignole e Acquasola*. Genova: De Ferrari.

Arobba, D. and Caramiello, R. 2011–2012. Indagine archeobotanica sui livelli del Riparo di Rocca Due Teste presso Alpicella (Varazze, Savona) pp. 157–166 in Bernabò Brea, M., Maggi, R. and Manfredini, A. (eds.), Il pieno Neolitico in Italia. *Rivista di Studi Liguri* LXXVII–LXXVIII.

Arobba, D., Biagi, P., Formicola, V., Isetti, E. and Nisbet, R. 1987. Nuove osservazioni sull'Arma dell'Aquila (Finale Ligure – Savona). *Atti della XXVI Riunione Scientifica dell' IIPP*, **II**, 541–51.

Arobba, D., Deferrari, G. and Nisbet, R. 1997. Carpological investigation at the cave of Arene Candide: an impression of caryopsis of barley on a ceramic sherd, pp. 119–24 in Maggi, R. (ed.), *Arene Candide: a Functional and Environmental Assessment of the Holocene Sequence*. Roma: Il Calamo.

Arobba, D., Caramiello, R. and Firpo, M. 2001. Studio paleobotanico e sedimentologico di un sondaggio alla foce del Fiume Centa (Albenga, *Liguria occidentale*). *Allionia* **38**, 147–58.

Arobba, D., Del Lucchese, A., Melli, P. and Caramiello, R. 2011–2012. Evidenze di scalvatura in rami di frassino del Neolitico medio a Genova, pp. 137–142 in Bernabò Brea, M., Maggi, R. and Manfredini, A. (eds.), Il pieno Neolitico in Italia. *Rivista di Studi Liguri* LXXVII–LXXVIII.

Bagolini, B. 1990. Aspects occidenttaux dans le Néolitithique de l'Italie septentrionale. Les vases a bouche carrée et la culture de Chassey-Lagozza, pp. 139–45 in Guilaine, J. and Gutherz, X. (eds.), *Autour de Jean Arnal*. Montpellier: Université des Sciences et techniques du Languedoc.

Bagolini, B. and Biagi, P. 1990. The radiocarbon chronology of the Neolithic and Copper age of northern Italy. *Oxford Journal of Archaeology* **9**, 1–23.

Ballara, M. 2002. *Per una ipotesi di scalvatura neolitica: aspetti tecnologici e sperimentali*. Tesi di Laurea, Università di Genova, Corso di Laurea in Conservazione dei Beni Culturali, 2001–2002. Genoa: University of Genoa.

Barfield, L. H., Bernabò Brea, M., Maggi, R. and Pedrotti, A. 2003. Processi di cambiamento culturale nel Neolitico dell'Italia Settentrionale, pp. 665–86 in *Atti della XXXV Riunione Scientifica, in memoria di Luigi Bernabò Brea, II*. Firenze: Istituto Italiano di Preistoria e Protostoria.

Barker, G. 1985. *Prehistoric Farming in Europe*. Cambridge: Cambridge University Press.

Barker, G. 2006. *The Agricultural Revolution in Prehistory. Why did Forgers become Farmers?* New York: Oxford University Press.

Barker, G., Biagi, P., Clark, G., Maggi, R. and Nisbet, R. 1990. From hunting to herding in the Val Pennavaira (Liguria – Northern Italy), pp. 99–121 in Biagi, P. (ed.), *The Neolithisation of the Alpine Region*. Brescia: Museo Civico Di Scienze Naturali.

Bar-Matthews, M., Ayalon, A. and Kaufman, A. 2000. Timing and hydrological conditions of Sapropel events in the Eastern Mediterranean as evident from speleothems, Soreq cave, Israel. *Chemical Geology* **169**, 145–56.

Bellini, C., Mariotti-Lippi, M. and Montanari, C. 2009. The Holocene landscape history of the NW Italian coasts. *The Holocene* **19**, 1161–72.

Berger, J. F. and Guilaine, J. 2009. The 8200 cal BP abrupt environmental change and the Neolithic transition: a Mediterranean perspective. *Quaternary International* **200**, 31–49.

Bernabò Brea, L. 1946. *Gli scavi nella caverna delle Arene Candide. Parte I. Gli strati con ceramiche, Collezione di monografie preistoriche ed archeologiche, 1*. Bordighera: Istituto di Studi Liguri.

Bernabò Brea, L. 1956. *Gli scavi nella caverna delle Arene Candide (Finale Ligure). Parte I. Gli strati con ceramiche, 2, campagne di scavo 1948–50, Collezione di monografie preistoriche ed archeologiche, 1*. Bordighera: Istituto di Studi Liguri.

Bernabò Brea, M., Maggi, R. and Manfredini, A. (eds.) 2011–2012. Il pieno Neolitico in Italia. *Rivista di Studi Liguri* LXXVII–LXXVIII.

Biagi, P. 1987. Il Neolitico della Liguria e del Piemonte, pp. 203–15 in *Atti delle Riunioni Scientifiche of IIPP*. Firenze: Istituto Italiano di Preistoria e Protostoria.

Biagi, P. and Spataro, M. 2001. Plotting the evidence: some aspects of the radiocarbon chronology of the Mesolithic-Neolithic transition in the Mediterranean basin. *Atti della Societàper la Preistoria e Protostoria della Regione Friuli-Venezia Giulia* **XII**(1999–2000), 15–54.

Biagi, P., Maggi, R. and Nisbet, R. 1987. Excavations at Arma dello Stefanin (Val Pennavaira – Albenga, northern Italy) 1982–1986. *Mesolithic Miscellany* **8**, 10–11.

Biagi, P., Starnini, E. and Voytek, B. 1993. The Late Mesolithic and Early Neolithic settlement of Northern Italy: recent considerations. *Porocilo o Raziskovanju Paleolita, Neolita in Eneolita v Sloveniji* **21**, 45–67.

Binder, D. and Lepère, C. in press. From Impresso-Cardial to SMP and Chassey in Provence, pp. 21–30 in Bernabò Brea, M., Maggi, R. and Manfredini, A. (eds.), Il Pieno Neolitico in Italia. Rivista di Studi Liguri LXXVII-LXXVIII (2011–2012).

Binder, D., Lepère, C. and Maggi, R. 2008. Epipaléolithique et Néolithique dans l'arc liguro-provencal: bilan et perspective de recherche. *Bulletin di Musée d'Anthropologie Préhistorique de Monaco, Supplément* **1**, 49–62.

Blasi, C. (ed.) 2010. *La vegetazione d'Italia*. Roma: Palombi and Partner.

Bond, G., Showers, W., Cheseby, M., Lotti, R., Almasi, P., deMenocal, P., Priore, P., Cullen, H., Hajdas, I. and Bonani, G. 1997. A pervasive millennial-scale cycle in North Atlantic Holocene and glacial climates. *Science* **278**, 1257–66.

Braggio Morucchio, G., Guido, M. A. and Montanari, C. 1988. Profilo palinologico e storia della vegetazione, pp. 94–96 in Gentile, S., Guido, M. A., Montanari, C., Paola, G., Braggio Morucchio, G. and Petrillo, M. (eds.), Ricerche geobotaniche e saggi di cartografia della vegetazione del piccolo bacino di Lago Riane (Liguria). *Braun-Blanquetia* **2**, 77–104.

Branch, N. P. 1997. Palynological study of the early and middle Neolithic cave deposits of Arene Candide: preliminary results, pp. 89–102 in Maggi, R. (ed.), *Arene Candide: a Functional and Environmental Assessment of the Holocene Sequence*. Roma: Il Calamo.

Branch, N. P. 2002. L'analisi palinologica per lo studio della vegetazione e della sua gestione, pp. 339–53 in Campana, N. and Maggi, R. (eds.), *Archeologia in Valle Lagorara*. Firenze: Istituto Italiano Di Preistoria e Protostoria.

Branch, N. P. 2004. Late Würm Lateglacial and Holocene environmental history of the Ligurian Apennines, Italy, pp. 7–69 in Balzaretti, R., Pearce, M. and Watkins, C. (eds.), *Ligurian Landscapes: Studies on Archaeology, Geography and History*. London: Accordia Research Institute.

Branch, N. P. 2013. Early – Middle Holocene vegetation history, climate change and human activities at Lago Riane (Ligurian Apennines, NW Italy). *Vegetation History and Archaeobotany* **22**, 315–34.

Brewer, S., François, L., Cheddadi, R., Laurent, J-M. and Favre, E. 2009. Comparison of simulated and observed vegetation for the mid-Holocene in Europe. *Climate of the Past Discussions* **5**, 965–1011.

Bronk Ramsey, C. 1995. Radiocarbon calibration and analysis of stratigraphy: the OxCal program. *Radiocarbon* **37**, 425–30.

Bronk Ramsey, C. 1998. Probability and dating. *Radiocarbon* **40**, 461–74.

Bronk Ramsey, C. 2001. Development of the radiocarbon program OxCal. *Radiocarbon* **43**, 355–63.

Bronk Ramsey, C. 2009. Bayesian analysis of radiocarbon dates. *Radiocarbon* **51**, 337–60.

Campana, N. and Franceschi, E. 1997. Analyses of the metal object, pp. 611–21 in Maggi, R. (ed.), *Arene Candide: a Functional and Environmental Assessment of the Holocene Sequence*. Roma: Il Calamo.

Campana, N. and Maggi, R. 2002. *Archeologia in Valle Lagorara.* Florence: Origines, Istituto Italiano di Preistoria e Protostoria.

Cantu, V. 1977. The climate of Italy, pp. 127–73 in Wallen, C. C. (ed.), *World Survey of Climatology 6, Climates of Central and Southern Europe*. Oxford: Elsevier.

Capelli, C., Mannoni, T. and Starnini, E. 2006. Tecniche produttive, materie prime e provenienza delle ceramiche preistoriche e protostotiche della Liguria, p1201–1208 in *Atti delle Riunione Scientifiche of IIPP, Materie prime e scambi nella Preistoria italiana*. Firenze: Istituto Italiano di Preistoria e Protostoria.

Cevasco, A., De Pascale, A., Guido, M. A., Montanari, C., Maggi, R. and Nicosia, C. 2013. Le Mogge di Ertola (Appennino Ligure): un contributo all'archeologia del fuoco ed all'archeologia dell'acqua, pp. 413–27 in Cevasco, R. (ed.), *La natura della montagna.* Sestri Levante: Oltre.

Cocchi Genick, D. 2012. *Le potenzialità informative delle ceramiche nell'analisi storica. Le forme vascolari dell'Età del Rame*. Verona: Qui Edit.

Colombaroli, D., Marchetto, A. and Tinner, W. 2007. Long-term interactions between Mediterranean climate, vegetation and fire regime at Lago di Massaciuccoli (Tuscany, Italy). *Journal of Ecology* **95**, 755–70.

Colombaroli, D., Vannière, B., Emmanuel, C., Magny, M. and Tinner, W. 2008. Fire–vegetation interactions during the Mesolithic–Neolithic transition at Lago dell'Accesa, Tuscany, Italy. *The Holocene* **18**, 679–92.

Colombaroli, D., Tinner, W., van Leeuwen, J., Noti1, R., Vescovi1, E., Vannière, B., Magny, M., Schmidt, R. and Bugmann, H. 2009. Response of broadleaved evergreen Mediterranean forest vegetation to fire disturbance during the Holocene: insights from the peri-Adriatic region. *Journal of Biogeography* **36**, 314–26.

Constantin, S., Bojar, A-V., Lauritzen, S-E. and Lundberg, J. 2007. Holocene and Late Pleistocene climate in the sub-Mediterranean continental environment: a speleothem record from Poleva Cave (Southern Carpathians, Romania). *Palaeogeography, Palaeoclimatology, Palaeoecology* **243**, 322–38.

Crepaldi, F. 2001. Le Chasséen en Ligurie. *Bulletin de la Société Préhistorique Française* **98**(3), 485–94.

Cruise, G. M. 1990. Pollen stratigraphy of two Holocene peat sites in the Ligurian Apennines, northern Italy. *Review of Palaeobotany and Palynology* **63**, 299–313.

Cruise, G. M., Macphail, R. I., Linderholm, J., Maggi, R. and Marshall, P. D. 2009. Lago di Bargone, Liguria, N Italy: a reconstruction of Holocene environmental and land-use history. *The Holocene* **19**, 987–1003.

Davis, B. A. S., Brewer, S., Stevenson, A. C., Guiot, J. and Data Contributors 2003. The temperature of Europe during the Holocene reconstructed from pollen data. *Quaternary Science Reviews* **22**, 1701–16.

De Lange, G. J., Thomson, J., Reitz, A, Slomp, C. P., Principato, M. S., Erba, E. and Corselli, C. 2008. Synchronous basin-wide formation and redox-controlled preservation of a Mediterranean sapropel. *Nature Geoscience* **1**, 606–10.

Del Lucchese, A. 2010. Le presenza umana nel Neolitico, pp. 10–2 in Del Lucchese, A. and Melli, P. (eds.), *Archeologia Metropolitana*. Genova: De Ferrari.

Drescher-Schneider, R., de Beaulieu, J-L., Magny, M., Walter-Simonnet, A-V., Bossuet, G., Millet, L., Brugiapaglia, E. and Drescher, A. 2007. Vegetation history, climate and human impact over the last 15,000 years at Lago dell'Accesa (Tuscany, Central Italy). *Vegetation History and Archaeobotany* **16**, 279–99.

Ferrari, A. and Steffè, G. 2006. Il sito di Bologna-via Andrea Costa nel quadro del Primo Neolitico dell'Italia centro-settentrionale, pp. 77–102 in Pessina, A. and Visentini, P. (eds.), *Preistoria dell'Italia Settentrionale*. Udine: Museo Friulano di Storia Naturale.

Ferraris, M. and Ottomano, C. 1997. Pottery analyses, pp. 339–48 in Maggi, R. (ed.), *Arene Candide: a Functional and Environmental Assessment of the Holocene Sequence*. Roma: Il Calamo.

Finsinger, W., Colombaroli, D., de Beaulieu, J-L., Valsecchi, V., Vannière, B., Vescovi, E., Chapron, E., Lotter, A. F., Magny, M. and Tinner, W. 2010. Early to mid-Holocene climate change at Lago dell'Accesa (central Italy): climate signal or anthropogenic bias? *Journal of Quaternary Science* **25**, 1239–47.

Fleitmann, D., Cheng, H., Badertscher, S., Edwards, R. L., Mudelsee, M., Gokturk, O. M., Fankhauser, A., Pickering, R., Raible, C. C., Matter, A., Kramers, J. and Tuysuz, O. 2009. Timing and climatic impact of Greenland interstadials recorded in stalagmites from northern Turkey. *Geophysical Research Letters* **36**, L19707.

Franco, C. 2011. *La fine del Mesolitico in Italia*. Trieste: Società per la Preistoria e Protostoria della Regione Friuli-Venezia Giulia, Quaderno 13.

Frisia, S., Borsato, A., Mangini, A., Spötl, C., Madonia, G. and Sauro, U. 2006. Holocene climate variability in Sicily from a discontinuous stalagmite record and the Mesolithic to Neolithic transition. *Quaternary Research* **66**, 388–400.

Gentile, S. 1982. Zonazione altitudinale della vegetazione in Liguria. *Lavori della Società Italiana di Biogeografia* **9**, 1–19.

Girod, A. 1997. Arene Candide: Holocene land snails, pp. 125–36 in Maggi, R. (ed.), *Arene Candide: a Functional and Environmental Assessment of the Holocene Sequence*. Roma: Il Calamo.

Grant, M. J., Waller, M. P. and Groves, J. A. 2011. The Tilia decline: vegetation change in lowland Britain during the mid and late Holocene. *Quaternary Science Reviews* **30**, 394–408.

Guido, M. A., Menozzi, B. I., Bellini, C., Placereani, S. and Montanari, C. 2013 A palynological contribution to the environmental archaeology of a Mediterranean mountain wetland (North West Apennines, Italy). *The Holocene* **23**, 1517–27.

Harris, D. R. (ed.) 1996. *The Origins and Spread of Agriculture and Pastoralism in Eurasia*. London: UCL Press.

Heuze, P., Schnitzler, A. and Klein, F. 2005. Is browsing the major factor of silver fir decline in the Vosges Mountains of France? *Forest Ecology and Management* **217**, 219–28.

Hoogerduijn Strating, E. H., Piccardo, G. B., Rampone, E., Scambelluri, M. and Vissers, R. L. M. 1990. The structure and petrology of the erro-tobbio peridotite, Voltri Massif, Ligurian Alps. Guidebook for a two-day-excursion with emphasis on processes in the upper mantle (Voltri Massif, June 26–28, 1989). *Ofioliti* **15**, 119–84.

Huntley, B., Bartlein, P. J. and Prentice, I. C. 1989. Climatic control of the distribution and abundance of beech (*Fagus* L.) in Europe and North America. *Journal of Biogeography* **16**, 551–60.

Issar, A. S. and Zohar, M. 2004. *Climate Change – Environment and Civilization in the Middle East*. Berlin: Springer.

Jalut, G., Dedoubat, J. J., Fontugne, M. and Otto, T. 2009. Holocene circum-Mediterranean vegetation changes: climate forcing and human impact. *Quaternary International* **200**, 4–18.

Leale Anfossi, M. 1953. Nuove ricerche preistoriche in Val Pennavaira. *Rivista Ingauna e Intemelia*, **III**(3–4), 65–7.

Lowe, J. J., Branch, N. and Watson, C. 1994a. The chronology of human disturbance of the vegetation of the northern Apennines during the Holocene, pp. 171–89 in Biagi, P. and Nandris, J. (eds.), *Highland zone exploitation in southern Europe*. Brescia: Museo Civico Di Scienze Naturali.

Lowe, J. J., Davite, C., Moreno, D. and Maggi, R. 1994b. Holocene pollen stratigraphy and human interference in the woodlands of the northern Apennines, Italy. *The Holocene* **4**, 153–64.

Macphail, R. I., Courty, M. A., Hather, J. and Wattez, J. 1997. The soil micromorphological evidence of domestic occupation and stabling activities, pp. 53–88 in Maggi, R. (ed.), *Arene Candide: a Functional and Environmental Assessment of the Holocene Sequence*. Roma: Il Calamo.

Maggi, R. 1983. Il Neolitico, ppp 45–58 in Maggi, R. (ed.), *Preistoria nella Liguria Orientale*. Recco: Siri.

Maggi, R. (ed.) 1990. *Archeologia dell'Appennino Ligure gli scavi del Castellaro di Uscio: un insediamento di crinale occupato dal Neolitico alla conquista Romana*. Collezione di Monografie Preistoriche ed Archeologiche 8. Bordighera (IM): Istituto Internazionale di Studi Liguri.

Maggi, R. 1996. Una palafitta neolitica in Val Bisagno?, pp. 376 in Melli, P. (ed.), *La Città Ritrovata*. Genova: Tormena.

Maggi, R. (ed.) 1997a. *Arene Candide: a Functional and Environmental Assessment of the Holocene Sequence*. Roma: Il Calamo.

Maggi, R. 1997b. The radiocarbon chronology, pp. 31–52 in Maggi, R. (ed.), *Arene Candide: a Functional and Environmental Assessment of the Holocene Sequence*. Roma: Il Calamo.

Maggi, R. 1997c. Summary: a modern excavation carried out fifty years ago, pp. 635–42 in Maggi, R. (ed.), *Arene Candide: a Functional and Environmental Assessment of the Holocene Sequence*. Roma: Il Calamo.

Maggi, R. 1999. Coasts and uplands in Liguria and Northern Tuscany from the Mesolithic to the Bronze Age, pp. 47–65 in Tykot, R. H., Morter, J. and Robb, J. E. (eds.), *Social Dynamics of the Prehistoric Central Mediterranean*. London: Accordia Research Institute.

Maggi, R. 2004. I monti sun eggi: the making of the Ligurian landscape in prehistory, pp. 71–82 in Balzaretti, R., Pearce, M. and Watkins, C. (eds.), *Ligurian Landscapes: Studies on Archaeology, Geography and History*. London: Accordia Research Institute.

Maggi, R. 2014. Prima di Chiavari, in Benente, F. and Campana, N. (eds.), *Antiche genti del Tigullio a Chiavari*, Chiavari-Bordighera. Bordighera (IM): Istituto Internazionale di Studi Liguri.

Maggi, R. Unpublished data. *I monti sono vecchi*. Genova: De Ferrari.

Maggi, R. and Campana, N. 2008. Archeologia delle risorse ambientali in Liguria: estrazione e sussistenza fra IV e III millennio BC. *Bulletin di Musée d'Anthropologie Préhistorique de Monaco, Supplément* **1**, 65–74.

Maggi, R. and Del Lucchese, A. 1988. Aspects of the Early Copper Age in Liguria. *Rassegna di Archaeologia* **7**, 331–8.

Maggi, R. and Nisbet, R. 1990. Prehistoric pastoralism in Liguria. *Rivista di Studi Liguri LVI*, **1–4**, 265–96.

Maggi, R. and Nisbet, R. 2000. Alberi da foraggio e scalvatura neolitica: nuovi dati dalle Arene Candide, pp. 289–308 in Pessina, A. and Muscio, G. (eds.), *La Neolitizzazione tra Oriente e Occidente*. Udine: Edizioni del Museo Friulano di Storia Naturale.

Maggi, R. and Pearce, M. 2005. Mid fourth-millennium copper mining in Liguria, north-west Italy: the earliest known copper mines in Western Europe. *Antiquity* **79**, 66–77.

Maggi, R. and Pearce, M. 2013. Cronologia mineraria in Liguria, pp. 5–15 in Cocchi, D. (ed.), *Cronologia assoluta e relativa dell'Età del Rame in Italia.* Verona: QuiEdit.

Maggi, R. and Starnini, E. 1997. Some aspects of the pottery production, pp. 279–337 in Maggi, R. (ed.), *Arene Candide: a Functional and Environmental Assessment of the Holocene Sequence*. Roma: Il Calamo.

Maggi, R. and Vignolo, M. R. 1984. Val Frascarese – Tana delle Fate, pp. 81–6 in Melli, P. (ed.), *Archeologia in Liguria II. Scavi e scoperte 1976–81*. Genova: Tormena Editore.

Maggi, R. and Vignolo, M. R. 1990. La ceramica dal Neolitico all'Età del Bronzo, pp. 127–68 in Maggi, R. (ed.), *Archeologia dell'Appennino Ligure, Gli scavi del Castellaro di Uscio*. Bordighera: Istituto Internazionale di Studi Liguri.

Maggi, R., Campana, N. and Pearce, M. 2011. Pirotecnologia e cronologia. Novità da Monte Loreto, pp. 281–7 in Giardino, C. (ed.), *Archeometallurgia: dalla conoscenza alla fruizione*. Bari: Edipuglia.

Magny, M., Miramont, C. and Sivan, O. 2002. Assessment of the impact of climate and anthropogenic factors on Holocene Mediterranean vegetation in Europe on the basis of palaeohydrological records. *Palaeogeography, Palaeoclimatology, Palaeoecology* **186**, 47–59.

Magny, M., Bégeot, C., Guiot, J. and Peyron, O. 2003. Contrasting patterns of hydrological changes in Europe in response to Holocene climate cooling phases. *Quaternary Science Reviews* **22**, 1589–96.

Magny, M., de Beaulieu, J-L., Drescher-Schneider, R., Vannière, B., Walter-Simonnet, A-V., Miras, Y., Bossuet, G., Peyron, O., Brugiapaglia, E. and Leroux, A. 2007. Holocene climate changes in the central Mediterranean as recorded by lake-level fluctuations at Lake Accesa (Tuscany, Italy). *Quaternary Science Reviews* **26**, 1736–58.

Magri, D. 2007. Patterns of post-glacial spread and the extent of glacial refugia of European beech (*Fagus sylvatica*). *Journal of Biogeography* **35**, 450–63.

Magri, D. and Sadori, L. 1999. Late Pleistocene and Holocene pollen stratigraphy at Lago di Vico, central Italy. *Vegetation History and Archaeobotany* **8**, 247–60.

Magri, D., Vendramin, G. G., Comps, B., Dupanloup, I., Geburek, T., Gömöry, D., Latalowa, M., Litt, T., Paule, L., Roure, J-M., Tantau, I., van der Knaap, W. O., Petit, R. J. and de Beaulieu, J-L. 2006. A new scenario for the Quaternary history of European beech populations: palaeobotanical evidence and genetic consequences. *New Phytologist* **171**, 199–221.

Mariotti, M. G. 1995. Osservazioni sulla vegetazione della Liguria. La vegetazione italiana. *Atti dei Convegni Lincei*. **115**, 189–227.

Mariotti-Lippi, M., Guido, M. A., Menozzi, B., Bellini, C. and Montanari, C. 2007. The Massaciuccoli Holocene pollen sequence and the vegetation history of the coastal plains by the Mar Ligure (Tuscany and Liguria, Italy). *Vegetation History Archaeobotany* **16**, 267–77.

Martino, G., Maggi, R. and Voytek, B. Unpublished data. The chipped industry of Pianaccia di Suvero. *Rivista di Studi Liguri* LVXXX.

Mayewski, P. A., Rohling, E. E., Stager, J. C., Karlen, W., Maasch, K. A., Meeker, L. D., Meyerson, A., Gasse, F., van Kreveld, S., Holmgren, K., Lee-Thorp, J., Rosqvist, G., Rack, F., Staubwasser, M., Schneider, R. R. and Steig, E. J. 2004. Holocene climate variability. *Quaternary Research* **62**, 243–55.

Melli, P. and Del Lucchese, A. (eds.) 1987. *Archeologia in Liguria III.1 Scavi e Scoperte 1982–86 Preistoria e Protostoria*. Genova: Soprintendenza Archeologica della Liguria.

Mercuri, A. M. 2008. Plant exploitation and ethnopalynological evidence from the Wadi Teshuinat area (Tadrart Acacus, Libyan Sahara). *Journal of Archaeological Science* **35**, 1619–42.

Mercuri, A. M., Florenzano, A., Massamba N'siala, I., Olmi, L., Roubis, D. and Sogliani, F. 2010. Pollen from archaeological layers and cultural landscape reconstruction: Case studies from the Bradano valley (Basilicata, southern Italy). *Plant Biosystems* **144**, 888–901.

Mercuri, A. M., Sadori, L. and Uzquiano Ollero, P. 2011. Mediterranean and north-African cultural adaptations to mid-Holocene environmental and climatic changes. *The Holocene* **21**, 189–206.

Montanari, C., Guido, M. A., Cornara, L. and Placereani, S. 1998. Tracce polliniche di boschi neolitici di abete bianco in Val Bisagno (area urbana di Genova). *Biogeographia* **19**, 133–43.

Moore, A. M. T. and Hillman, G. C. 1992. The Pleistocene to Holocene transition and human economy in southwest Asia: the impact of the Younger Dryas. *American Antiquity* **57**, 482–94.

Myers, P. G. and Rohling, E. J. 2000. Modeling a 200-Yr interruption of the Holocene Sapropel S1. *Quaternary Research* **53**, 98–104.

Negrino, F. and Starnini, E. 2003. Patterns of lithic raw material exploitation in Liguria from the Palaeolithic to the Copper Age, pp. 235–43 in *Les matières premières lithiques en Préhistoire*. Préhistroire du sud-ouest, Supplèment 5. Cressenac (France): Association Préhistoire du Sud-Ouest.

Nisbet, R. 1997. Arene Candide: charcoal remains and prehistoric woodland use, pp. 103–12 in Maggi, R. (ed.), *Arene Candide: a Functional and Environmental Assessment of the Holocene Sequence*. Roma: Il Calamo.

Nisbet, R. 2006. Agricoltura del Neolitico Antico alle Arene Candide (Savona), pp. 331–5 in Cucuzza, N. and Medri, M. (eds.), *Archeologie, Studi in onore di Tiziano Mannoni*. Bari: Edipuglia.

Ottomano, C. 2004. L'evoluzione paleoambientale del territorio di Chiavari attraverso l'analisi e l'interpretazione di sondaggi geognostici, pp. 81–4 in De Marinis, R. C. and Spadea, G. (eds.), *I Liguri*. Milano: Skira.

Parker, A. G., Goudie, A. S., Anderson, D. E., Robinson, M. A. and Bonsall, C. 2002. A review of the mid-Holocene elm decline in the British Isles. *Progress in Physical Geography* **26**, 1–45.

Pearce, M. 2000. What this awl means. Understanding the earliest Italian metalwork, pp. 67–73 in Ridgway, D., Serra Ridgway, F. R., Pearce, M., Herring, E., Whitehouse, R. D. and Wilkins, J. B. (eds.), *Ancient Italy in its Mediterranean Setting, Studies in honour of Ellen Macnamara*. Accordia Specialist Studies on the Mediterranean 4. London: Accordia Research Centre.

Pearce, M. 2013. *Rethinking the North Italian Early Neolithic*. Accordia Specialist Studies on Italy 17. London: Accordia Research Centre.

Peltier, A., Touzet, M-C., Armengaud, C. and Ponge, J-F. 1997. Establishment of *Fagus sylvatica* and *Fraxinus excelsior* in an old-growth beech forest. *Journal of Vegetation Science* **8**, 13–20.

Pessina, A. and Tinè, V. 2008. *Archeologia del Neolitico*. Roma: Carocci.

Peyron, O., Goring, S., Dormoy, I., Kotthoff, U., Pross, J., de Beaulieu, J-L., Drescher-Schneider, R., Vannière, B. and Magny, M. 2011. Holocene seasonality changes in the central Mediterranean region reconstructed from the pollen sequences of Lake Accesa (Italy) and Tenaghi Philippon (Greece). *The Holocene* **21**, 131–46.

Rambeau, C., Finlayson, B., Smith, S., Black, S., Inglis, R. and Robinson, S. A. 2011. Palaeoenvironmental reconstruction at Beidha, southern Jordan (c. 18,000–8500 BP): implications for human occupation during the Natufian and Pre-Pottery Neolithic, pp. 245–68 in Mithen, S. J. and Black, E. (eds.), *Water, Life and Civilisation: Climate, Environment and Society in the Jordan Valley*. Cambridge: Cambridge University Press.

Ramrath, A., Sadori, L. and Negendank, J. F. W. 2000. Sediments from Lago di Mezzano, central Italy: A record of Lateglacial/Holocene climatic variations and anthropogenic impact. *The Holocene* **10**, 87–95.

Reimer, P. J., Baillie, M. G. L., Bard, E., Bayliss, A., Beck, J. W., Bertrand, C., Blackwell, P. G., Buck, C. E., Burr, G., Cutler, K. B., Damon, P. E., Edwards, R. L., Fairbanks, R. G., Friedrich, M., Guilderson, T. P., Hughen, K. A., Kromer, B., McCormac, F. G., Manning, S., Bronk Ramsey, C., Reimer, R. W., Remmele, S., Southon, J. R., Stuiver, M., Talamo, S., Taylor, F. W., van der Plicht, J. and Weyhenmeyer, C. E. 2004. IntCal04 terrestrial radiocarbon age calibration, 0–26 cal kyr BP. *Radiocarbon* **46**, 1029–58.

Rius, D., Vannière, B. and Galop, D. 2012. Holocene history of fire, vegetation and land use from the central Pyrenees (France). *Quaternary Research* **77**, 54–64.

Roberts, N., Jones, M. D., Benkaddour, A., Eastwood, W. J., Filippi, M. L., Frogley, M. R., Lamb, H. F., Leng, M. J., Reed, J. M., Stein, M., Stevens, L., Valero-Garcés, V. and Zanchetta, G. 2008. Stable isotope records of Late Quaternary climate and hydrology from Mediterranean lakes: the ISOMED synthesis. *Quaternary Science Reviews* **27**, 2426–41.

Roberts, N., Brayshaw, N., Kuzucuoğlu, C., Perez, R. and Sadori, L. 2011. The mid-Holocene climatic transition in the Mediterranean: causes and consequences. *The Holocene* **21**, 3–13.

Rowley-Conwy, P. 1997. The animal bones from Arene Candide (Holocene sequence): final report, pp. 153–279 in Maggi, R. (ed.), *Arene Candide: a Functional and Environmental Assessment of the Holocene Sequence*. Roma: Il Calamo.

Rowley-Conwy, P. 2012. Distinguishing Wild Boar from Domestic Pigs in Prehistory: A Review of Approaches and Recent Results. *Journal of World Prehistory* **25**, 1–44.

Sadori, L. and Narcisi, B. 2001. The Postglacial record of environmental history from Lago di Pergusa, Sicily. *The Holocene* **11**, 655–70.

Sadori, L., Jahns, S. and Peyron, O. 2011. Mid-Holocene vegetation history of the central Mediterranean. *The Holocene* **21**, 117–29.

Sadori, L., Ortu, E., Peyron, O., Zanchetta, G., Vannière, B., Desmet, M. and Magny, M. 2013. The last 7 millennia of vegetation and climate changes at Lago di Pergusa (central Sicily, Italy). *Climate of the Past Discussions* **9**, 2059–94.

Skeates, R. and Whitehouse, R. (eds.) 1994. *Radiocarbon Dating and Italian Prehistory*. Archaeological Monographs of the British School at Rome 8 and Accordia Specialist Studies on Italy 3. London: British School at Rome and Accordia Research Centre.

Spotl, C., Mangini, A. and Richards, D. A. 2006. Chronology and palaeoenvironment of Marine Isotope Stage 3 from two high-elevation speleothems, Austrian Alps. *Quaternary Science Reviews* **25**, 1127–36.

Starnini, E. 1999. Industria litica scheggiata, pp. 219–36 and 451–71 in Tinè, S. (ed.), *Il Neolitico nella Caverna delle Arene Candide (scavi 1972–77)*. Bordighera: Istituto Internazionale di Studi Liguri.

Starnini, E. and Vicino, G. 1993. Segnalazione di un sito neolitico in località S. Sebastiano di Perti (Finale Ligure-SV). *Rassegna di Archeologia* **11**, 37–43.

Starnini, E. and Voytek, B. 1997a. The Neolithic chipped stone artefacts from the Bernabò Brea-Cardini excavations, pp. 349–426 in Maggi, R. (ed.), *Arene Candide: a Functional and Environmental Assessment of the Holocene Sequence*. Roma: Il Calamo.

Starnini, E. and Voytek, B. 1997b. New lights on old stones: the ground stone assemblage from Bernabò Brea excavation at Arene Candide, pp. 427–511 in Maggi, R. (ed.), *Arene Candide: a Functional and Environmental Assessment of the Holocene Sequence*. Roma: Il Calamo.

Stuiver, M. and Polach, H. A. 1977. Reporting of 14C data. *Radiocarbon* **19**, 355–63.

Stuiver, M. and Reimer, P. J. 1986. A computer program for radiocarbon age calculation. *Radiocarbon* **28**, 1022–30.

Tinè, S. 1974. Il Neolitico a l'eta del Bronzo in Liguria alla luce delle recenti scoperte. *Atti XVI Riunione Scientifica IIPP*, 37–57.

Tinè, S. (ed.) 1999a. *Il Neolitico nella Caverna delle Arene Candide (scavi 1972–1977)*. Collezione di Monografie Preistoriche ed Archeologiche, 10. Bordighera: Istituto Internazionale di Studi Liguri.

Tinè, V. 1999b. Transizione tra Neolitico Antico e Neolitico Medio: le ceramiche dello stile Pollera. Strato 13, pp. 142–80 in Tinè, S. (ed.) *Il Neolitico nella Caverna delle Arene Candide (scavi 1972–77)*. Bordighera: Istituto Internazionale di Studi Liguri.

Tinner, W., Hubschmid, P., Wehrli, M., Ammann, B. and Conedera, M. 1999. Long-term forest-fire ecology and dynamics in southern Switzerland. *Journal of Ecology* **87**, 273–89.

Tinner, W., Conedera, M., Gobet, E., Hubschmid, P., Wehrli, M. and Ammann, B. 2000. A palaeoecological attempt to classify fire sensitivity of trees in the southern Alps. *The Holocene* **10**, 565–74.

UNESCO-FAO. 1969. *Ecological study of the Mediterranean zone, vegetation map of the Mediterranean zone and explanatory notes*. Arid Zone Research 30. Paris: UNESCO.

Valsecchi, V., Finsinger, W., Tinner, W. and Ammann, B. 2008. Testing the influence of climate, human impact and fire on the Holocene population expansion of *Fagus sylvatica* in the southern Prealps (Italy). *The Holocene* **18**, 603–14.

van der Knaap, W. O., van Leeuwen, J. F. N., Finsinger, W., Gobet, E., Pini, R., Schweizer, A., Valsecchi, V. and Ammann, B. 2005. Migration and population expansion of *Abies*, *Fagus*, *Picea*, and *Quercus* since 15,000 years in and across the Alps, based on pollen-percentage threshold values. *Quaternary Science Reviews* **24**, 645–80.

Vannière, B., Colombaroli, D., Chapron, E., Leroux, A., Tinner, W. and Magny, M. 2008. Climate versus human-driven fire regimes in Mediterranean landscapes: the Holocene record of Lago dell'Accesa (Tuscany, Italy). *Quaternary Science Reviews* **27**, 1181–96.

Vannière, B., Power, M. J., Roberts, N., Tinner, W., Carrión, J., Magny, M., Bartlein, P., Colombaroli, D., Daniau, A. L., Finsinger, W., Gil-Romera, G., Kaltenrieder, P., Pini, R., Sadori, L., Turner, R., Valsecchi, V. and Vescovi, E. 2011. Circum-Mediterranean fire activity and climate changes during the mid-Holocene environmental transition (8500–2500 cal. BP). *The Holocene* **21**, 53–73.

Vescovi, E., Ammann, B., Ravazzi, C. and Tinner, W. 2010a. A new Late-glacial and Holocene record of vegetation and fire history from Lago del Greppo, northern Apennines, Italy. *Vegetation History and Archaeobotany* **19**, 219–33.

Vescovi, E., Kaltenreider, P. and Tinner, W. 2010b. Late-Glacial and Holocene vegetation history of Pavullo nel Frignano (Northern Apennines, Italy). *Review of Palaeobotany and Palynology* **160**, 32–45.

Walker, D. S. 1960. *The Mediterranean Lands*. London: Methuen.

Watson, C. 1996. The vegetational history of the northern Apennines, Italy: information from three new sequences and a review of regional vegetational changes. *Journal of Biogeography* **23**, 805–41.

Weninger, B., Alram-Stern, E., Bauer, E., Clare, L., Danzeglocke, U., Jöris, O., Kubatzki, C., Rollefson, G., Todorovag, H. and van Andel, T. 2006. Climate forcing due to the 8200 cal yr BP event observed at Early Neolithic sites in the eastern Mediterranean. *Quaternary Research* **66**, 401–20.

Wick, L. and Möhl, A. 2006. The mid-Holocene extinction of silver fir (*Abies alba*) in the Southern Alps: a consequence of forest fires? Palaeobotanical records and forest simulations. *Vegetation History Archaeobotany* **15**, 435–44.

Yu, G. and Harrison, S. P. 1996. An evaluation of the simulated water balance of Eurasia and northern Africa at 6000 yr BP using lake status data. *Climate Dynamics* **12**, 723–35.

Zanchetta, G., Drysdale, R. N., Hellstrom, J. C., Fallick, A. E., Isola, I., Gagan, M. K. and Pareschi, M. T. 2007. Enhanced rainfall in the Western Mediterranean during deposition of sapropel S1: stalagmite evidence from Corchia cave (Central Italy). *Quaternary Science Reviews* **26**, 279–86.

Zilhão, J. 2003. The Neolithic Transition in Portugal and the Role of Demic Diffusion in the Spread of Agriculture across West Mediterreanean Europe, pp. 207–26 in Ammerman, A. J. and Biagi, P. (eds.), *The Widening Harvest.* Boston: Archaeological Institute of America, Colloquia and Conference, 6.

Zhornyak, L. V., Zanchetta, G., Drysdale, R. N., Hellstrome, J. C., Isola, I., Regattieri, E., Piccini, L., Baneschi, I. and Couchoud, I. 2011. Stratigraphic evidence for a "pluvial phase" between ca 8200–7100 ka from Renella cave (Central Italy). *Quaternary Science Reviews* **30**, 409–17.