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Saggi

Late Würm and Early-Middle Holocene Environmental Change and Human Activities in the Northern Apennines, Italy

Nicholas P. Branch*,
Lionello Morandi**

Abstract

An enhanced radiocarbon-dated pollen-stratigraphical record from Rovegno (Liguria, 812m asl), northern Apennines (Italy), has provided a history of vegetation succession from before 17,056-16,621 cal yrs BP to the present day. The record indicates the transition

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from open *Pinus* woodland to *Artemisia* dominated grassland, and finally *Juniperus* shrubland during the late Würm. This is succeeded by *Betula* and *Pinus* woodland, and the expansion of thermophilous taxa, namely *Abies*, *Corylus* and *Quercus* during the Late Würm Lateglacial Interstadial. The 'Younger Dryas' is possibly represented by an increase in *Betula* and *Artemisia*. During the early Holocene, mixed coniferous-deciduous woodland is dominant with *Quercus*, as well as *Abies*, *Fagus* and *Corylus*. *Fagus* woodland becomes established sometime before 6488-6318 cal yrs BP, but never becomes a major component of the woodland cover. Throughout the middle Holocene, *Abies* woodland fluctuates, with marked declines between 6488-6318 cal yrs BP and 5287-4835 cal yrs BP, although the cause remains uncertain. Finally, the paper evaluates the application of non-pollen palynomorphs, especially coprophilous fungal spores, at Prato Spilla 'A' (Emilia Romagna) and concludes that greater caution must be used when interpreting middle Holocene human activity based upon pollen data alone.

Una migliore risoluzione cronologica basata su date radiocarboniche per una sequenza pollinica da Rovegno (812 m asl, Appennino settentrionale ligure, Italia), ha permesso di ricostruire i cambiamenti vegetazionali per un periodo compreso da prima di 17,056-16,621 anni cal BP ad oggi. La sequenza mostra il passaggio da un bosco a *Pinus* con struttura aperta ad una prateria dominata da *Artemisia*, ed infine un arbusteto a *Juniperus* nel tardo Würm. Successivamente si sviluppa un bosco a *Pinus* e *Betula*, e verso la fine dell'ultimo interstadiale würmiano ha luogo l'espansione di taxa termofili quali *Abies*, *Corylus* e *Quercus*. Il 'Dryas recente' è forse rappresentato da un aumento in *Betula* e *Artemisia*. Durante l'Olocene antico prevale il bosco misto a conifere e latifoglie decidue con presenza di *Quercus*, oltre che *Abies*, *Fagus* e *Corylus*. La faggeta appare stabilirsi poco prima di 6488-6318 anni cal BP, senza tuttavia mai divenire una componente principale della copertura forestale. Nel corso dell'intero Olocene medio si verificano oscillazioni nelle percentuali del bosco ad *Abies*, con cali decisi tra 6488-6318 anni cal BP e 5287-4835 anni cal BP, sebbene per cause ancora da chiarire. Infine, l'articolo si sofferma sull'applicazione dei palinomorfi non pollinici, in particolare spore di funghi coprofilici, al sito di Prato Spilla 'A' (Emilia Romagna), sottolineando come sia necessario adoperare grande cautela nella interpretazione di attività antropiche medio oloceniche, quando ci si basi unicamente su dati pollinici.

Introduction

Palaeoecological studies in the Northern Apennines (embracing the regions of Liguria, and parts of Tuscany and Emilia-Romagna; fig. 1) have enabled reconstruction of the main patterns of environmental change from ~14,000 to ~3000 years before present (Late Würm Late Glacial to the end of the middle Holocene)¹. Recent investigations have attempted to enhance understanding

¹ Cruise 1990a, 1990b; Braggio *et al.* 1991; Lowe *et al.* 1994a, 1994b; Watson 1996; Branch 2002, 2004.

of the cause, or causes, of these changes through improved integration with archaeological and palaeoclimatic data². The aim of this paper is to present a new chronological framework for the palaeoecological record from Rovegno³, a unique upland site in Liguria, spanning from before ~17,000 cal yrs BP (Upper Palaeolithic) to the present day. This will be briefly compared with palaeoecological data from across the Northern Apennines with a particular emphasis on summarising the key phases of vegetation succession. Finally, we present a brief evaluation of the use of non-pollen palynomorphs as a means of identifying human impact on the environment during the middle Holocene from a new study at Prato Spilla 'A', Emilia-Romagna⁴.

Study area and site description

In the eastern Ligurian Apennines, the geology is dominated by upper Jurassic Ophiolites (basalts, serpentinites, gabbros and granites) and associated sedimentary deposits⁵. In the Tuscan-Emilian Apennines, the key sites are located in an area of Cretaceous formations and Oligocene sandstone with interbedded 'olistostrome' units with "clasts of limestone, calcarenites, greywackes, sandstones and breccias"⁶. Above 1200m asl, but occasionally extending down to 800m asl, glacial landforms and deposits (cirques and moraines) have been recorded in the Tuscan-Emilian Apennines, and are probably Würm in age⁷. The vegetation cover may be broadly divided into four main zones: (1) The Mediterranean zone (from sea level to ~200m 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 (~200-1000m 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 (~1000-1500m asl) is dominated by *Fagus sylvatica*, with *Quercus cerris*, *Acer pseudoplatanus* and *Fraxinus excelsior*. (4) The sub-Alpine zone (from ~1500m asl) with coniferous woodland dominated by *Pinus sylvestris*, *P. cembra*, *Larix decidua* and *Abies alba*, and *Pinus mugo*,

² Menozzi *et al.* 2007; Bellini *et al.* 2009; Cruise *et al.* 2009; Vescovi *et al.* 2010; Branch 2013; Guido *et al.* 2013; Branch and Marini 2014; Branch *et al.* 2014.

³ Branch 2004.

⁴ See Lowe *et al.* 1994b; see Morandi (in preparation) for a more detailed discussion of the study of Prato Spilla 'A'.

⁵ See Carta Strutturale dell'Appennino Settentrionale, Foglio 4; Abbate *et al.* 1982.

⁶ Watson 1996, p. 806.

⁷ Losacco 1982.

Juniperus and Ericaceous heath in the Apennines⁸.

The archaeological scheme indicates that lowland-inland and coastal areas were the geographical foci for occupation during the Upper Palaeolithic and during the Early and Middle Neolithic (~7800-6100 cal yrs BP; ‘Impressed Ware’ and ‘Square Mouthed’ pottery cultures) (fig. 2 and fig. 3a). Mesolithic sites were situated at mid and high elevations from ~11,700-7800 cal yrs BP (fig. 2). By the Late Neolithic (~6100 cal yrs BP; ‘Chassey’ culture) farming practices were taking place over a wide altitudinal range (~800-1500m asl). These practices continued into the Copper Age (~5800-4200 cal yrs BP) and Early Bronze Age (~4200-3800 cal yrs BP) with the creation of key sites on important watersheds (fig. 3b). During the Mid-Late Bronze Age (~3800-2900 cal yrs BP), the record indicates a change in the organisation of settlements and management of landscape resources⁹.

The small basin of Rovegno (44° 34' 33" N 9° 17' 12" E) is located at an altitude of 812m on the eastern side of the upper Trebbia valley and near to the small town of Rovegno (fig. 1). The site is a small mire basin, approximately 75m in length (longest axis) and 55m in width, and with a catchment area of approximately 0.6km². Two streams that drain in a northwest direction towards the Fosso del Riccio and River Trebbia dissect the basin. Southeast of the basin the topography rises to 825m and forms the Pian di Prao, a plain that extends to approximately 875m below the slopes of Poggio Carmine (1097m). The geology consists of lower Cretaceous and upper Jurassic ophiolitic complexes and Jasper outcrops, extensive colluvial deposits and some Palaeocene sandstones (‘Casanova’). The Carta Geologica d’Italia (Foglio 83) has also mapped areas of glacial drift deposits, mainly in the area between Fontanigorda and Casanova. The present day mire vegetation is dominated by species of Poaceae, *Equisetum* sp., *Ranunculus* sp. and *Mentha aquatica*. The dryland vegetation is dominated by *Castanea sativa*, *Corylus avellana* (coppiced) and *Fagus sylvatica* (coppiced), with *Pinus sylvestris*, *Quercus* sp., *Prunus* sp. and *Pteridium aquilinum*. Prato Spilla ‘A’ (44°21' N 02° 21' W) is located at 1550m, at the source of the Rio Cedra (fig. 1). It is a small basin measuring approximately 90m in length (longest axis) and 50m in width, “up-valley from a prominent moraine ridge”¹⁰.

⁸ UNESCO-FAO 1969; Gentile 1982; Mariotti 1995; Blasi 2010.

⁹ Maggi 1990, 1999, 2004.

¹⁰ Lowe 1992, p. 195.

Methods

Rovegno

The field survey procedures involved auguring and coring to establish the sub-surface sediment architecture and suitable locations for sampling for palaeoecological analyses. Core samples were obtained using a Stitz percussion corer, and the physical properties, composition and humification of the sediments recorded using the Troels-Smith procedure¹¹. Pollen grains and spores were extracted following standard procedures, involving sub-sampling 1cm³ using a volumetric sampler, dispersal in 1% Sodium pyrophosphate, sieving through 5µm and 150µm meshes to remove fine and coarse mineral and organic matter, removal of mineral matter using Sodium polytungstate (specific gravity of 2g/cm³), acetolysis and mounting in glycerol jelly¹². Pollen grains and spores were identified using type collections and the following sources of keys and photographs¹³. Plant nomenclature follows the Flora Europaea.

A total of 300 pollen grains (excluding aquatics and spores) were recorded for each sample. The results are expressed as a percentage of total land pollen (trees, shrubs and herbs) and divided into eleven local pollen assemblage zones (LPAZs ROV-1 to ROV-11). Zonation of the pollen diagram into Local Pollen Assemblage Zones (LPAZ) was carried out using constrained cluster analysis within TILIA2 (not shown; calculated using Edwards and Cavalli-Sforza chord distance [square root transformation]), coupled with visual discrimination of the main and subsidiary changes in pollen stratigraphy¹⁴. The radiocarbon determinations were calibrated using the maximum intercept method¹⁵, OxCal version 4.0.1¹⁶, and the internationally agreed dataset for terrestrial samples from the northern hemisphere¹⁷. The full age range (rounded to 10 years) is quoted as 'cal yrs BP'.

Prato Spilla 'A'

The field investigations involved taking a 730cm long core using a Russian peat sampler from the central part of the basin (fig. 4). Subsamples of 1cm³ were taken from the core every 8cm from the part of the sequence comprised between 730-602cm, and every 16cm between 602 and 442cm, for analysis of the non-

¹¹ Troels-Smith 1955.

¹² Branch *et al.* 2005.

¹³ Moore *et al.* 1991; Reille 1992.

¹⁴ Grimm 1991-2011; see also Birks and Gordon 1985.

¹⁵ Stuiver and Reimer 1986.

¹⁶ Bronk Ramsey 1995, 2001, 2007.

¹⁷ Reimer *et al.* 2004.

pollen palynomorphs (NPP). The core has then been correlated to previous work¹⁸ based on the main pollen phases and depositional discontinuities¹⁹. Microscope slides were prepared at the University of Reading following acetolysis treatment prior to mounting in glycerol jelly²⁰. A high number of microfossils have also been identified in oil immersion at x1000 magnification. NPP values are expressed as percentages of Total Non-Pollen Palynomorph Sum (TNPP)²¹. Slides from modern samples and a number of articles were used as reference material for the identifications²². Counts averaged 460 NPPs, ranging from 361 to 630 total microfossils per sample, and including a minimum 200 fungal spores or algal NPPs²³.

Rovegno: sedimentary and vegetation history

The data generated by the palaeoecological study of Rovegno²⁴ (fig. 5; tab. 1 and tab. 2), and enhanced radiocarbon-based chronology (this study), indicates that prior to 17,056-16,621 cal yrs BP (ROV-1) until 15,099-14,501 cal yrs BP (ROV-3) sediment was deposited in a freshwater lake and sedge-swamp comprising marginal aquatic vegetation (400-257cm). The dryland vegetation was characterised by the succession from open *Pinus* woodland and short-turf grassland (ROV-1) to *Artemisia* dominated grassland (ROV-2), and finally *Juniperus* shrubland (ROV-3). These taxa suggest the colonisation of arctic-tundra, steppe or semi-desert plant communities associated with cold and possibly dry climatic conditions during the late Würm glaciation.

The period from 15,099-14,501 cal yrs BP to the onset of the Holocene at ~11,700 cal yrs BP (ROV-3 to ROV-6a; 257-221cm) is complex with evidence for organic lake sedimentation (257-247cm), herbaceous peat formation (247-225cm), and finally a return to mineral-rich lake sediment deposition (225-221cm). The establishment of pioneer *Juniperus* shrubland (ROV-3) is succeeded by *Betula* and *Pinus* woodland (ROV-3), and the expansion of *Abies*, *Corylus* and *Quercus* (ROV-4 and ROV-5). The timing of the transition corresponds to the onset of the Late Würm Lateglacial Interstadial. LPAZ ROV-6a (230-221cm) is marked by the decline of *Pinus*, an increase in *Betula* and *Artemisia*, and the continued expansion of *Abies*, *Quercus* and *Corylus* woodland. This zone may represent a temporary hiatus and/or reduction in sedimentation at the Lateglacial to early Holocene transition, or during the Late Würm Lateglacial

¹⁸ Lowe 1992; Lowe *et al.* 1994b.

¹⁹ Bedford 2013.

²⁰ Branch *et al.* 2005.

²¹ Mazier *et al.* 2009; Cugny *et al.* 2010.

²² van Geel *et al.* 2003; García *et al.* 2004; Doveri 2007; Vujanovic and Goh 2009; Cugny *et al.* 2010.

²³ See Morandi (in preparation) for a full discussion of the NPP study.

²⁴ Branch 2004.

Stadial ('Younger Dryas'), because it is succeeded by an 'abrupt' increase in mixed deciduous and coniferous woodland, and the formation of well humified herbaceous peat and lake sediment deposition (ROV-6b; 221-197cm).

Thereafter, the mire community becomes fully established forming *Alnus* Carr woodland (ROV-6c to ROV-10; 197-80cm) from 6488-6318 cal yrs BP to sometime after 5287-4835 cal yrs BP. This is succeeded by a period of colluviation and an absence of pollen preservation in the mineral rich sediments. The dryland vegetation is characterised by the establishment of mixed deciduous woodland dominated by *Quercus* with *Abies*, *Fagus* and *Corylus*. *Fagus* woodland becomes established at Rovegno sometime before 6488-6318 cal yrs BP, but never becomes a major component of the woodland cover. Throughout the Holocene, *Abies* woodland fluctuates, with marked declines between 6488-6318 cal yrs BP and 5287-4835 cal yrs BP, especially at the beginning of zones ROV-7, ROV-8 and ROV-9. This corresponds to marked increases in herbaceous taxa and changes in peat composition²⁵. The thickness of the colluvial deposit (100cm) indicates a magnitude of erosion and sediment deposition several times greater than recorded at other sites in the northern Apennines²⁶, and may be due to a natural catastrophic event or long-term, intensive human activity, during the Copper/Bronze Age cultural period or later.

Discussion

The updated palaeoecological record from Rovegno has provided a unique insight into the environmental history of the northern Apennines during the late Würm glacial period, the Late Würm Lateglacial Interstadial and possibly the Late Würm Lateglacial Stadial ('Younger Dryas'). Rovegno has also provided a record spanning the Holocene, although there are several differences in sediment accumulation rate and composition, and vegetation succession, with other sites in the northern Apennines, which may be due to local characteristics, such as the glacial history, geomorphology and elevation, as well as the sub-regional intensity and nature of human activities²⁷.

Late Glacial

The Late Würm pollen record from Rovegno (prior to 17,056-16,621 cal yrs BP to ~15,000 cal yrs BP) has indicated an open vegetation structure, dominated

²⁵ See Branch 2004 for the full pollen diagram.

²⁶ Branch 2004.

²⁷ See Branch and Marini 2014; Branch *et al.* 2014.

by herbaceous plant taxa, especially *Artemisia*, which is consistent with cold and/or dry (arid) climatic conditions recorded elsewhere in parts of Italy²⁸, and southern Europe generally²⁹, at this time. The presence of *Pinus* woodland prior to 17,056-16,621 cal yrs BP at Rovegno is particularly interesting and suggests the onset of 'warmer' climatic conditions following the last glacial maximum. In contrast, the decline of *Pinus* at approximately 17,056-16,621 cal yrs BP suggests the renewal of colder conditions, which coincides with a period of isotopic enrichment in several Mediterranean lakes³⁰ and may be provisionally equated with the North Atlantic Heinrich 1 (H1) rapid climate change event. Unfortunately, there are no comparable records of this age from the northern Apennines and hence Rovegno provides a potentially important contribution to our understanding of millennial scale climate and environmental change in northern Italy during the last glaciation.

Pollen-stratigraphic records from the northern Apennines spanning the Late Würm Lateglacial, from ~15,000 cal yrs BP to the onset of the Holocene at ~11,700 cal yrs BP, are few in number³¹. At Prato Spilla 'C' (1350m asl), for example, the vegetation succession is quite different to that of Rovegno, with the Lateglacial Interstadial (~14,340 cal yrs BP) denoted by the expansion of *Abies*, *Quercus* and *Corylus* together with *Pinus*, which was succeeded by *Abies* and *Pinus* woodland during the Lateglacial Stadial³². The evidence for the 'Younger Dryas' event (H0 or Greenland Stadial 1) at Prato Spilla 'C' is highly significant, although the published radiocarbon dates do not support the clear pollen signature for the renewal of colder climatic conditions i.e. the expansion of herbaceous taxa, notably Caryophyllaceae and Chenopodiaceae. At Lago del Greppo, the succession from *Juniperus* shrubland to *Pinus* woodland with minor amounts of *Abies* and *Corylus* during the Lateglacial Interstadial is similar to that recorded at Rovegno³³. Therefore, the paucity of *Abies* in the Lateglacial pollen data from Rovegno is perhaps the most important contrast with Prato Spilla 'C', and may be explained by differences in elevation and proximity of glacial refugia. This interpretation is broadly supported by pollen-stratigraphic records from southern Italy³⁴, which suggest that *Abies* was absent. The decline of *Pinus* woodland sometime after 13,387-13,163 cal yrs BP at Rovegno may possibly be equated with the 'Younger Dryas' event. The absence of a clear expansion of herbaceous taxa in the pollen record, however, suggests that

²⁸ E.g. Watts *et al.* 1996a; Finsinger *et al.* 2006.

²⁹ Roberts *et al.* 2008.

³⁰ Roberts *et al.* 2008.

³¹ Lowe 1992; Lowe and Watson 1993; Lowe *et al.* 1994b; Watson 1996; Branch 2004; Cruise *et al.* 2009; Vescovi *et al.* 2010.

³² Lowe 1992.

³³ Vescovi *et al.* 2010.

³⁴ Watts *et al.* 1996b.

the event is poorly represented. This possibly agrees with the pollen record from Lago del Greppo, where the event also appears to be poorly represented or absent³⁵. The return of colder climatic conditions at this time has been recorded in several lake sequences in the Mediterranean³⁶ and Italy³⁷, whilst in the Northern Apennines, Prato Spilla 'A' has indicated the clear expansion of herbaceous taxa and the dominance of open *Pinus* woodland, and lesser amounts of *Abies*, during the same period (~12,581 cal yrs BP)³⁸.

Early Holocene

The transition to the early Holocene at Rovegno was denoted by the succession from shrubland to open woodland communities, dominated by *Abies*, *Quercus* and *Corylus*. At Prato Spilla 'A' and 'C' the pollen records indicate a similar expansion of thermophilous taxa, although the nearest radiocarbon dates following the transition, at 12,175 cal yrs BP and 12,477 cal yrs BP (respectively), seem incompatible with the widely recognised date for the onset of the Holocene at ~11,700 cal yrs BP³⁹. The onset of sedimentation at ~10,500 cal yrs BP at Lago Riane marked the expansion of mixed deciduous – coniferous woodland, comprising *Abies* with *Pinus*, *Betula*, *Fraxinus* and *Quercus*⁴⁰, which is consistent with data from Rovegno. However, whilst all high elevation sites confirm that during the early Holocene *Abies* was a dominant component within the woodland cover, at mid-altitudes, such as Rovegno, *Quercus* was equally important⁴¹.

The timing of the colonisation of *Corylus*, from ~10,500–9500 cal yrs BP, appears to have been broadly similar across the Northern Apennines⁴². Although a complex picture has emerged for the precise timing and successional dynamics of the 'Corylus rise' in central and southern Europe⁴³, the data from the Northern Apennines do appear to be consistent with adjacent areas. Interestingly, at Rovegno the 'abrupt' nature of the 'Corylus rise' (ROV-6b) suggests that it occurred following a hiatus in sedimentation during the earliest

³⁵ Vescovi *et al.* 2010.

³⁶ Roberts *et al.* 2008.

³⁷ E.g. Watts *et al.* 1996a; Allen *et al.* 2002; Finsinger *et al.* 2006.

³⁸ Lowe 1992; Lowe *et al.* 1994b.

³⁹ Lowe 1992; we accept that a number of studies in Italy indicate that the Holocene may have commenced later (e.g. 10,300 cal yrs BP), however the temporal resolution at Rovegno does not provide a precise indication of the timing of the transition to the early Holocene, and ~11,700 cal yrs BP has been used because it is an internationally accepted date; see Heiri *et al.* 2007, Belis *et al.* 2008, and Mercuri *et al.* 2002 for a range of dates for the start of the Holocene in Italy.

⁴⁰ Branch 2013.

⁴¹ Cruise 1990a, 1990b; Lowe 1992; Watson 1996; Cruise *et al.* 2009; Vescovi *et al.* 2010.

⁴² E.g. Lowe 1992; Watson 1996; Vescovi *et al.* 2010; Branch 2013.

⁴³ See Finsinger *et al.* 2006.

Holocene. The timing and duration of the hiatus remains uncertain, but the cessation in sedimentation may be consistent with other sites, such as Lago Riane⁴⁴. The cause of the ‘*Corylus* rise’ has been attributed to climate change, distance from glacial refugia, and the migration rate of *Corylus*, competition or Mesolithic human activities⁴⁵ (see fig. 2). Unfortunately, the data from Rovegno add very little to the current debate, although given the archaeological evidence for human activities in the mountains at this time, this cannot be excluded as a possibility.

For the remainder of the early Holocene, *Abies* dominated the upland zone of the Northern Apennines, forming a mixed coniferous-deciduous woodland cover with *Quercus*, *Tilia*, *Ulmus* and *Corylus*⁴⁶. At lower elevations, sites such as Rovegno and Lago di Bargone⁴⁷, indicate a higher proportion of *Quercus* within the *Abies* woodland, the declining importance of *Pinus*, and the increasing presence of *Fagus*. The presence of *Fagus* at lower elevations is consistent with data from Lagorara, where it is co-dominant with *Abies* from ~7600 cal yrs BP⁴⁸.

Middle Holocene

The onset of the Middle Holocene (~7000-6000 cal yrs BP) was marked by contrasting vegetation patterns in the upland zone of the Northern Apennines: (a) a sustained reduction in *Abies* woodland (e.g. Lago Rotondo), (b) a temporary decline (e.g. Lago Riane, Lago Padule and Lago Pratignano), (c) the persistence of *Abies* (e.g. Prato Spilla ‘A’ and Lago del Greppo), and (d) the broadly synchronous expansion of *Fagus* woodland⁴⁹. This general pattern coincided with increases in *Quercus* and *Corylus*, and herbaceous taxa (e.g. *Plantago lanceolata*), and a reduction in *Tilia*, *Ulmus* and *Fraxinus*. At lower elevations, *Fagus* woodland was already well established at Lagorara⁵⁰, whilst at Lago di Bargone⁵¹ and Rovegno⁵² *Quercus* became increasingly dominant over *Abies*. The presence of *Fagus* from 6488-6318 cal yrs BP at Rovegno confirms that this taxon colonised mid-altitudes prior to its major expansion at higher elevations from ~6000 cal yrs BP⁵³.

⁴⁴ Branch 2013.

⁴⁵ Peyron *et al.* 2011; Branch 2013.

⁴⁶ Lowe *et al.* 1994b; Vescovi *et al.* 2010.

⁴⁷ Cruise *et al.* 2009.

⁴⁸ Branch 2002; Branch and Marini 2014.

⁴⁹ Lowe *et al.* 1994b; Montanari *et al.* 1998; Bellini *et al.* 2009; Vescovi *et al.* 2010.

⁵⁰ Branch 2002.

⁵¹ Cruise *et al.* 2009.

⁵² Branch 2004.

⁵³ See Vescovi *et al.* 2010; Branch 2013.

From ~6000 cal yrs BP, *Fagus* formed mixed *Abies-Fagus* woodland across the upland zone of the Northern Apennines, which coincided with further reductions in *Ulmus*, *Tilia* and *Fraxinus*, increases in herbaceous taxa (e.g. *Plantago lanceolata* and Poaceae), as well as *Carpinus* and *Ostrya*. At lower elevations, *Quercus* became dominant, with *Fagus* only forming a minor component of the woodland cover; whilst coastal wetlands record an increase in tree heath communities⁵⁴. The period from ~4700 cal yrs BP to the end of the middle Holocene (~3000 cal yrs BP) records a further major change in vegetation succession with the beginning of a sustained reduction in *Abies* woodland, and an overall increase in *Fagus*, which suggests dynamic changes in the composition and structure of the woodland cover⁵⁵. It is at this time that several sites show a sustained increase in shrubland and herbaceous taxa, indicating important changes in the vegetation structure of the northern Apennines. A number of studies have reviewed the regional transition to *Fagus* dominated woodland at higher elevations, and it is apparent that there are variations in the timing, and the relative importance of climate change and human activities remains uncertain⁵⁶. At lower elevation sites, the situation is complex with vegetation changes occurring against a background of increasing levels of human activity. The decline of the main woodland taxa at many sites was accompanied by occasional evidence for soil erosion and a general increase in non-arboreal taxa, especially during the Late Neolithic (~6100-5800 cal yrs BP), Copper Age (~5800-4200 cal yrs BP) and Bronze Age (~4200-2900 cal yrs BP) (see fig. 3a and 3b). Although these changes are often associated with the spread of agriculture in many parts of Europe, the palaeoecological evidence for human activities at mid and high elevations in the Northern Apennines sometimes remains equivocal⁵⁷. In contrast, the archaeological evidence for Early Neolithic human activities employing a broad-spectrum economy in lowland, coastal areas is overwhelming⁵⁸. From the Late Neolithic onwards, however, the zooarchaeological and archaeobotanical evidence lends greater support to the palaeoecological data, which infers greater human disturbance at mid to high elevations, including management, caused by pastoralism and the creation of upland pastures, as well as the utilisation of woodland fodder for sheep/goats, pigs and cattle as part of a system of transhumance⁵⁹. It has been argued that human activity may have been responsible, therefore, for the changes in woodland composition that occurred across the Northern Apennines at this time⁶⁰.

⁵⁴ Bellini *et al.* 2009; Cruise *et al.* 2009.

⁵⁵ Baffico *et al.* 1987; Cruise 1990b; Lowe *et al.* 1994b; Vescovi *et al.* 2010.

⁵⁶ E.g. Branch and Marini 2014.

⁵⁷ Cruise *et al.* 2009; Branch 2013.

⁵⁸ Maggi 1997, 2004.

⁵⁹ Maggi 1999, 2004.

⁶⁰ See Branch 2013; Branch and Marini 2014; Branch *et al.* 2014; Mercuri *et al.* 2014.

The application of standard criteria for inferring human impact on the environment using palaeoecological data, such as woodland clearance, biomass burning and soil erosion remains uncertain, however, unless supported by direct evidence, such as cereal pollen indicating localised cultivation. Additional methods must therefore be routinely employed in Northern Apennine research, including better integration with environmental archaeological datasets⁶¹. The potential of new approaches for investigating human activities has been shown by the application of non-pollen palynomorph (NPP) analysis, especially coprophilous fungal spores, for detecting pastoralism, to a new middle Holocene sedimentary sequence from Prato Spilla 'A'⁶² (fig. 6 and fig. 7). Previous detailed pollen analysis at the site has inferred two episodes of human interference in vegetation succession during the Middle and Late Neolithic. The events were characterised by a decline in *Ulmus* and *Fraxinus* woodland (labelled M1; ~6400 cal yrs BP), and the expansion of *Fagus* woodland (labelled M2; ~5800 cal yrs BP)⁶³. The second event in particular coincided with an increase in herbaceous taxa suggesting a significant change in woodland structure and composition. The low values of coprophilous fungal spores across both of these events in the current study suggest, however, that there is little or no evidence for human activity associated with pastoralism. The percentage values appear to be relatively steady, whilst an increase in the obligate coprophilous taxa should be expected if derived from domesticated flocks. Instead, the dung spores could be ascribed to wild mountain herbivores, most likely ungulates (e.g. *Capreolus capreolus*, *Rupicapra rupicapra*, *Cervus elaphus*) and lagomorphs (*Lepus* spp.) (fig. 6 and fig. 7)⁶⁴. This view seems to be supported by the distance from Prato Spilla of late prehistoric finds (25-30 km), and ongoing concerns over the existence of long-range prehistoric pastoralism at this time⁶⁵. The situation is made more complicated, however, by the estimated small size of Neolithic groups⁶⁶, which may have resulted in low palaeoecological visibility, even if they were active in the surrounding landscape. These fungal spore data provide some support therefore for the hypothesis advocated by Lowe *et al.*⁶⁷ for the M1 event: that human groups may have been impacting upon the vegetation cover some distance from Prato Spilla 'A'. The interpretation of the M2 event is more contentious, with the fungal spore data suggesting no human activity associated with animal husbandry at Prato Spilla 'A' despite the arguments presented by Lowe *et al.* 1994b⁶⁸. The fungal data suggest, therefore, that greater caution

⁶¹ Menozzi *et al.* 2010; Mercuri *et al.* 2014.

⁶² Morandi (in preparation).

⁶³ Lowe *et al.* 1994b.

⁶⁴ Morandi (in preparation); Richardson 1972; Rowley-Conwy 1997; Lorenzini *et al.* 2002; Spagnesi and De Marinis 2002.

⁶⁵ Marzatico 2007.

⁶⁶ Maggi and Nisbet 1990.

⁶⁷ Lowe *et al.* 1994b.

⁶⁸ Lowe *et al.* 1994b.

must be used when interpreting human activity based upon pollen data alone, and innovative mixed method approaches are recommended instead⁶⁹.

In addition to human activities, a number of alternative explanations may be advanced for the changes in woodland cover recorded during this period including disease, natural burning and climate change, which may have accelerated the spread of *Fagus* woodland in particular⁷⁰. During the latter half of the Holocene Thermal Maximum (~11,000-5000 cal yrs BP), the central western Mediterranean experienced declining winter precipitation and temperatures, and increasingly colder, wetter summers⁷¹. These changes may explain the progressive decline in *Abies* populations across a wide altitudinal range due to changes in the length of the growing season, and may have facilitated the spread / displacement of *Fagus* due to higher summer precipitation. This evidence for a change in climate in the western Mediterranean, especially after ~6000 cal yrs BP, is consistent with other Italian and Northern Hemispheric proxy records⁷². Therefore, despite the archaeological evidence for increasing human presence in mountainous areas from the Middle to Late Neolithic onwards, caution must be taken when interpreting palaeoecological data, especially when expressing the magnitude of human impact on the environment, due to the unequivocal evidence for climate change.

Conclusions

The enhanced radiocarbon dated palaeoecological record from Rovegno has provided a new and important contribution to our understanding of vegetation succession and climate change in the Northern Apennines. The radiocarbon chronology indicates that sediment initiation commenced prior to 17,056-16,621 cal yrs BP; Rovegno therefore represents the oldest published pollen stratigraphic record in the region (Branch 2004). The presence of distinctive vegetation changes during the late Würm glacial period and the Late Würm Lateglacial Interstadial indicate pronounced climatic changes during this period. The evidence for the Late Würm Lateglacial Stadial ('Younger Dryas') remains uncertain. Nevertheless, the pollen record indicates interesting differences in vegetation history compared to other Lateglacial sequences from the northern Apennines, which may be attributed to elevation and distance from glacial refugia. During the early and middle Holocene, the main phases of

⁶⁹ E.g. see Giguët-Covex *et al.* 2014; Mercuri *et al.* 2014.

⁷⁰ See Baffico *et al.* 1987; Lowe *et al.* 1994b; Brewer *et al.* 2009; Jalut *et al.* 2009; Vescovi *et al.* 2010; Peyron *et al.* 2011.

⁷¹ Brewer *et al.* 2009; Jalut *et al.* 2009; Peyron *et al.* 2011; Renssen *et al.* 2012.

⁷² E.g. Bond *et al.* 1997; Mayewski *et al.* 2004; Mercuri *et al.* 2011; Lauterbach *et al.* 2012.

vegetation succession at Rovegno are consistent with other sites in the northern Apennines, and indicate that *Quercus* and *Abies* were the dominant woodland cover at this elevation. The colonisation of *Fagus*, and the progressive decline of *Abies*, may be attributed to several possible causes including human activity or climate change, or both. It is apparent, therefore, that additional methods must be routinely employed to avoid circular arguments inherent in the use of pollen data, especially where there is an absence of direct evidence for human activities e.g. cereal pollen. The application of coprophilous fungi at Prato Spilla 'A', together with pollen analysis, has shown the value of this mixed method approach when attempting to (1) identify human activity in the absence of clear indicators, (2) differentiate between local and regional pollen-stratigraphical signatures of human activity, and (3) identifying the possible role of wild and domesticated herbivores in vegetation change.

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Appendix

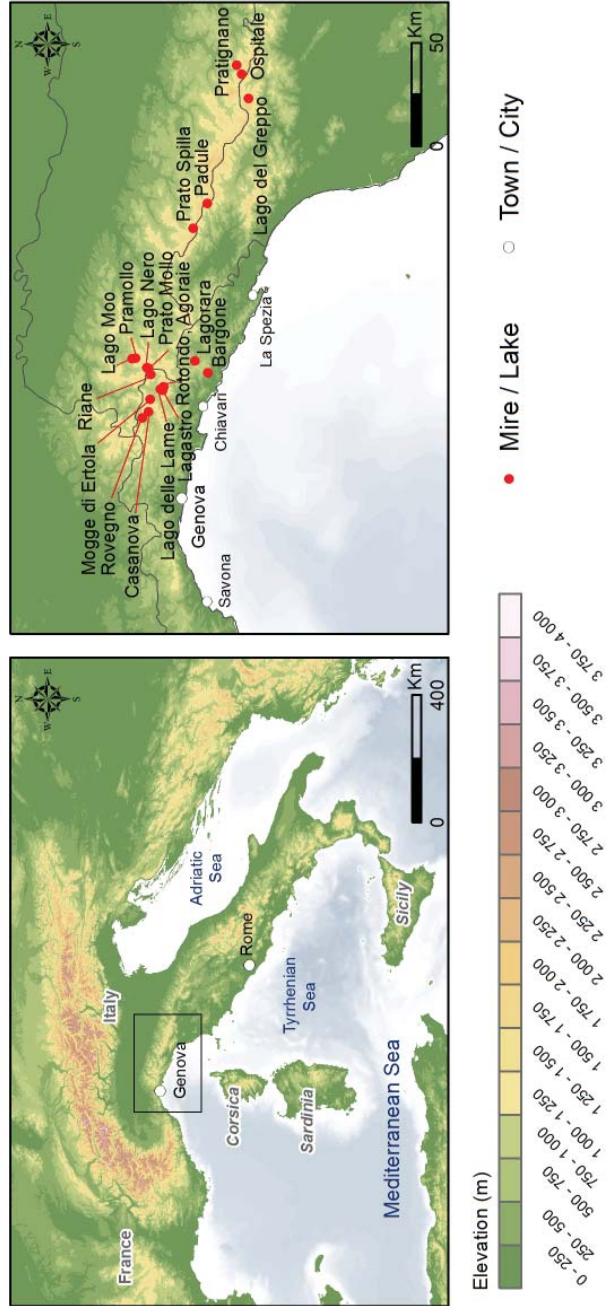


Fig. 1. Location of the study area and key palaeoecological records from the northern Apennines, Italy

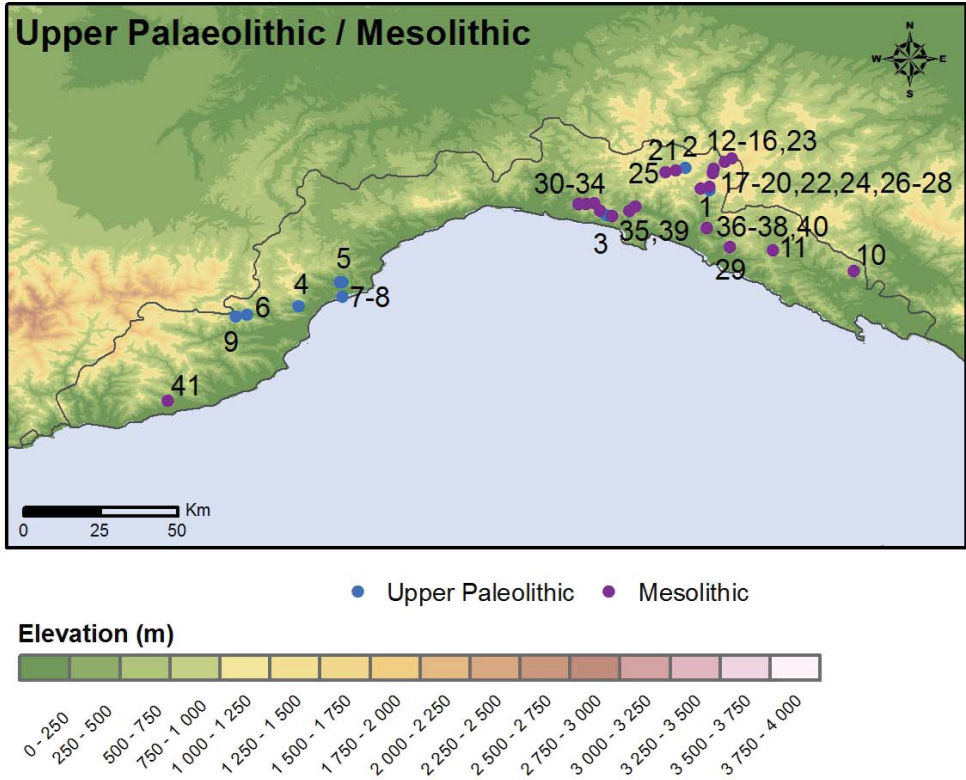


Fig. 2. Key Upper Palaeolithic and Mesolithic archaeological sites in the Ligurian Apennines: Moglie (1), Pian Brogione (2), Uccellato (3), Toirano (4), Caverna del Frate (5), Arma di Nasino (6), Arene Candide (7), Arma dell'Aquila (8), Arma dello Stefanin (9), Suvero (10), Torza (11), Ragola (12), Prato della Cipolla (13), Passo dello Zovallo (14), Monte Penna E (15), Monte Penna W (16), Prato Mollo (17), Lago Nero (18), Lago Agoraie (19), Pian Moglie (20), Passo Esola (21), Bosco delle Lame (22), Groppo Rosso (23), Colmo Rondio (24), Pian Brogione (25), Pian Gasparelle (26), Malga Perlezzi (27), Giacopiane (28), Bargone (29), Traso Monte (30), Monte Tregin (31), Uccellato (32), Nasoni (33), Passo Bastia (34), Uscio (35), Passo della Camilla (36), Monte Bianco (37), Nido del Merlo (38), Ferranda (39), Mezzanego (40), Pian del Re (41)

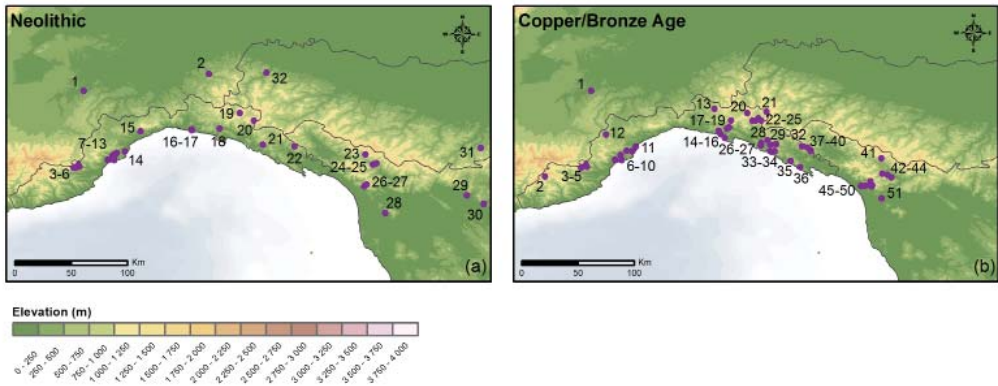


Fig. 3a. Key Neolithic archaeological sites in the northern Apennines: Alba (1), Cecima (2), Tana del Barletta (3), Arma di Nasino (4), Grotta Pertusello (5), Arma dello Stefanin (6), Grotta del Ponte di Vara (7), Pollera Cave (8), Grotta dell'Edera (9), Caverna del Frate (10), Arene Candide (11), Arma dell'Aquila (12), Caverna Le Pile (13), Caverna dell'Acqua (14), Alpicella (15), Genova Piazza Brignole (16), Genova Piazza della Vittoria (17), Castellaro di Uscio (18), Pian Brogione (19), Aiona (20), Tana delle Fate (21), Pianaccia di Suvero (22), Monte Frignone II (23), Pian di Cerreto (24), Muraccio (25), Riparo del Lauro (26), Grotta all'Onda (27), San Rossore Poggio di Mezzo (28), Spazzavento (29), Neto di Bolasse (30), Grotta di Monte Venere (31), Travo (32)

Fig. 3b. Key Copper Age and Bronze Age archaeological sites in the northern Apennines: Alba (1), Il Pertuso (2), Tana del Barletta (3), Arma di Nasino (4), Grotta Pertusello (5), Grotta del Ponte di Vara (6), Caverna del Frate (7), Arene Candide (8), Grotta delle Vacche (9), Caverna dell'Acqua (10), Bergeggi (11), Bric Tana (12), Monte Porcile (13), Uccellato (14), Recco (15), Camogli (16), Castellaro di Uscio (17), Ferrada (18), Corsiglia (19), Piano Brogione (20), Drusco (21), Aiona (22), Prato Mollo (23), Bosco delle Lame (24), Giacopiane (25), Val Frascaiese (26), Libiola & Monte Loreto (27), Lagorara (28), Grotta Prima Ciappa (29), Tana delle Fate (30), Torza (31), Cota (32), Mezzema (33), Monte Carmo (34), Pignone (35), Monte Parodi (36), Pianaccia di Suvero (37), Zignago (38), Vezzola (39), Veppo (40), Grotta della Guerra – Villa Collemantina (41), Grotta delle Fate di Calomini (42), Buca di Castelvenere – Fabbriche di Vallico (43), Buca delle Fate di Cardoso (44), Buca dei Goti (45), Grotta del Tanaccio & Grotta delle Pianacce (46), Grotta della Penna Buia (47), Grotta del Tambugione (48), Tana della Volpe (49), Buca della Giga (50), Buca Tana di Maggiano (51)



Fig. 4. Prato Spilla 'A' (north facing)

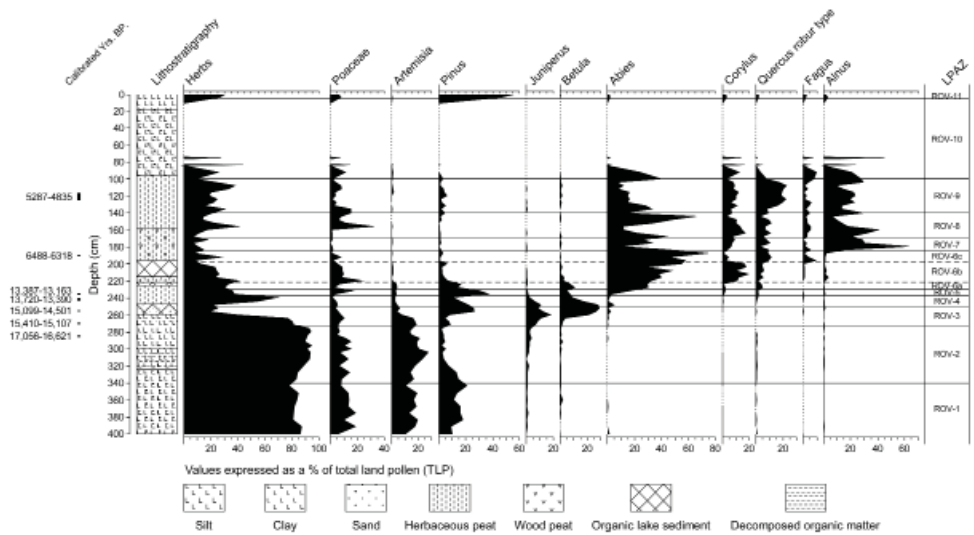


Fig. 5. Rovegno. Selected taxa pollen diagram. Values expressed as a % of total land pollen

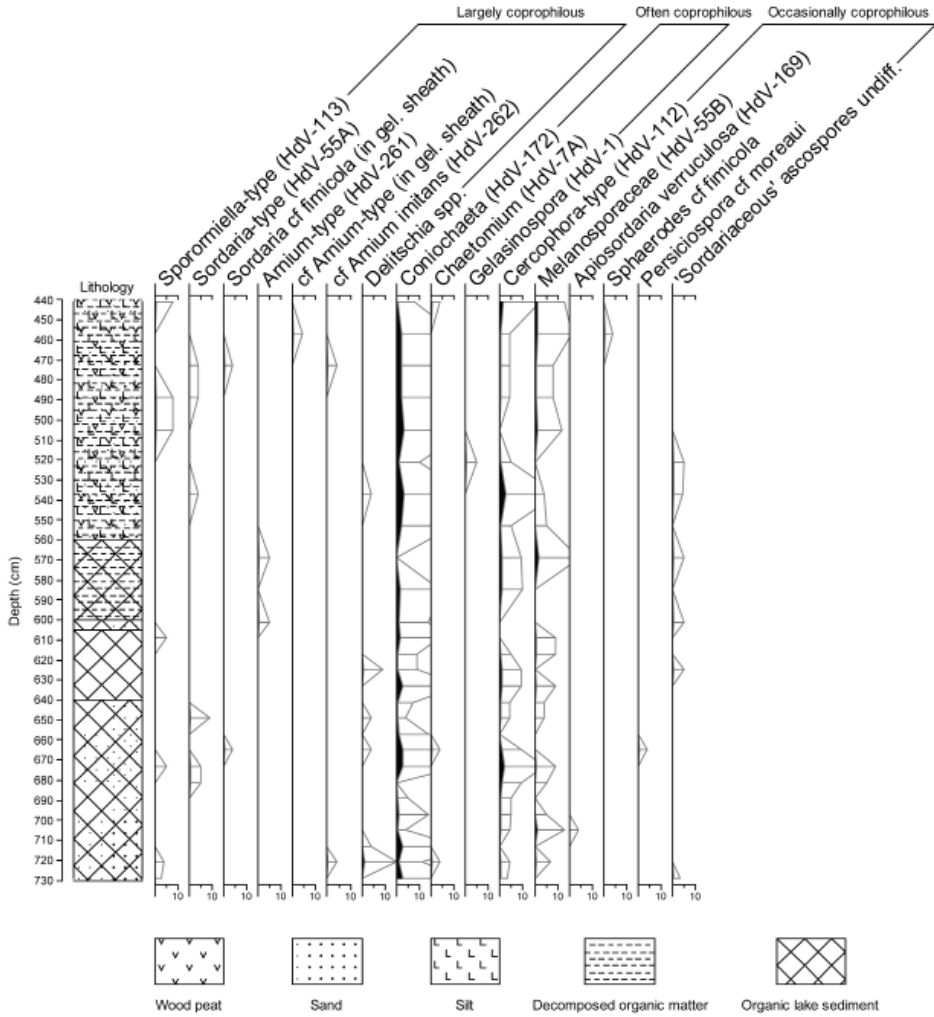


Fig. 6. Prato Spilla 'A'. Selected taxa NPP diagram (x10 exaggeration). Values expressed as % of total fungal spores + algal NPPs. Ecological groupings according to Krug *et al.* 2004



Fig. 7. Prato Spilla 'A'. Obligat and potentially coprophilous fungal spores: a. type 55B (Melanosporaceae) b. *Cercophora*-type (t. 112) c. *Sporormiella*-type (t. 113) d. *Delitschia* sp. e. *Sordaria*-type (t. 55A). Scale bar = 10 μ m

Local Pollen Assemblage Zone (LPAZ)	Depth (cm)	Key pollen taxa
ROV-1	400 – 340 cm	Herbaceous taxa – <i>Pinus</i>
ROV-2	340 – 272 cm	Herbaceous taxa
ROV-3	272 – 250 cm	<i>Betula</i> – <i>Pinus</i> – <i>Juniperus</i>
ROV-4	250 – 237 cm	Cyperaceae – <i>Betula</i> – <i>Pinus</i>
ROV-5	237 – 230 cm	<i>Pinus</i> – Herbaceous taxa
ROV-6	230 – 185 cm	<i>Abies</i> – <i>Quercus</i> – <i>Corylus</i> – <i>Fraxinus</i>
ROV-6a ROV-6b ROV-6c	230 – 221 cm 221 – 197 cm 197 – 185 cm	Peak in <i>Betula</i> pollen (12%) Expansion of <i>Corylus</i> pollen (19%) Dominance of <i>Abies</i> pollen (75%)
ROV-7	185 – 170 cm	<i>Alnus</i> – <i>Abies</i>
ROV-8	170 – 140 cm	<i>Abies</i> – <i>Alnus</i>
ROV-9	140 – 100 cm	<i>Abies</i> – <i>Alnus</i> – <i>Quercus</i>
ROV-10	100 – 5 cm	<i>Abies</i> – <i>Alnus</i> – <i>Dryopteris</i> type
ROV-11	5 – 1 cm	<i>Pinus</i> – <i>Castanea</i> – <i>Equisetum</i>

Tab. 1. Local Pollen Assemblage Zones for Rovegno (see Branch 2004 for full details)

Depth (cm)	Laboratory Code	Uncalibrated years BP	Calibrated years BP (cal yrs BP)	$\delta^{13}\text{C}$ ‰	Material
116-125	Beta-106212	4380 ±80	5287-4835	-28.8	Sedge and grass peat
190-191	CAMS-164199	5635 ±35	6488-6318	-25	Sedge and grass peat
235-236	CAMS-164200	11,435 ±40	13,387-13,163	-25	Sedge and grass peat
240-243	Beta-104794	11,690 70	13,720-13,390	-27.5	Sedge and grass peat
255-256	CAMS-164201	12,530 ±35	15,099-14,501	-25	Organic lake sediment
270-271	CAMS-164202	12,800 ±35	15,410-15,107	-25	Organic sediment
285-286	CAMS-164203	13,915 ±40	17,056-16,621	-25	Organic sediment

Tab. 2. Radiocarbon dates from Rovegno

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