The changing face of the Mediterranean – Land cover, demography and environmental change: Introduction and overview

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(Article begins on next page)

The changing face of the Mediterranean: land cover, demography, and environmental change. Introduction and overview

Bevan, A., [1] Palmisano, A., [1] Woodbridge, J.,[2] Fyfe, R., [2] Roberts, N., [2] Shennan, S. [1]

1. Institute of Archaeology, University College London, 31-34 Gordon Square, London WC1H 0PY, UK

2. School of Geography, Earth and Environmental Sciences, University of Plymouth, Drake Circus, Plymouth PL4 8AA, UK,

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Abstract

This paper introduces a special issue on *The Changing Face of the Mediterranean: Land Cover, Demography, and Environmental Change* which brings together up-to-date regional or thematic perspectives on major long term trends in Mediterranean human-environment relations. Particularly important insights are provided by palynology to reconstruct past vegetation and land cover, and archaeology to establish long-term demographic trends, but with further significant input from palaeoclimatology, palaeofire research and geomorphology. Here, we introduce the rationale behind this pan-Mediterranean research initiative, outline its major sources of evidence and method, and describe how individual submissions work to complement one another.

Keywords

pollen; radiocarbon;archaeology; settlement; demography; land cover; vegetation

1. Introduction

The Mediterranean provides a globally-famous, data-rich location in which to explore the long-term relationship between changes in human population, climate and land cover, as well as the role of other natural or anthropogenic impacts. Over the course of the Holocene, this sea’s terrestrial fringes have played host to the precocious development of strikingly complex, highly connected human societies, and it is unsurprising to find clear evidence for an often radical, transformative impact made on Mediterranean landscapes by human action, to the extent that the latter is to some extent a defining characteristic (Grove and Rackham, 2001; Horden and Purcell 2000; Broodbank 2013; Walsh 2014). However, beyond a centuries-old claim that humanity's misdeeds brought ruin to a Mediterranean Eden, what has the exact role of human population rise-and-fall been in the creation of the Mediterranean lands people see and live in today? How regionally varied is the story of the coalescence of its vegetation communities? To what extent has the spatial structure of settlement – with people dispersed across many small habitations or nucleated into major towns and cities, focused on coastal areas or predominantly inland – moved in step with other changes? How closely associated with these other trends are Mediterranean erosion and fire regimes, often proposed as two characteristic features of its unusual ecosystems?

At a time when the long-term vulnerability or sustainability of human-environmental relations is of intense interest worldwide, the Mediterranean is extremely well-suited to provide a deep historical perspective and critical insights, both at small and large scales (e.g. Butzer 2005; Bevan and Conolly 2013). However, so far, basin-wide pollen-based syntheses of Mediterranean Holocene dynamics have tended to prioritise reconstruction of natural vegetation rather than anthropogenic land cover (e.g. Jalut et al. 2009, Collins et al. 2012), while integrated studies of human-landscape interactions have largely been restricted to single geographical areas and/or discrete time periods (e.g. Frenzel 1994; Barker and Mattingly 1999-2001). The papers that follow in this special issue all have the above challenges in mind and arise from a workshop at the Santuari de Lluc (Tramuntana, Mallorca) in September 2017, that was held under the auspices of a three-year, UK-based Leverhulme Trust funded research project entitled *The Changing the Face of the Mediterranean: Land Cover and Population Since the Advent of Farming*. Collectively they attempt to synthesise what we currently know about major long term trends in Mediterranean human-environment relations, drawing upon evidence from disciplines spanning the natural sciences, social sciences and humanities, including palynology as a means of reconstructing past vegetation and land cover, archaeology in order to establish long-term demographic trends, and further insights from palaeoclimatology, palaeofire research and geomorphology. The papers compare and contrast these various archives in order to provide integrated histories of landscape change for different parts of the Mediterranean. In so-doing they look to open up dialogue about both temporal trends of continuity or change in Mediterranean life over the last twelve millennia, and geographic patterns of consistency and divergence across the basin.

2. Sources and Methods

Pollen Archives

Fossil pollen archives from sediment cores have long been a key resource for localised landscape and land cover reconstruction, although broad-scale studies have often been limited by dating imprecision and data coverage. Over the last two decades, methods have become increasingly sophisticated and greater efforts have concentrated on improving the quality of large databases and their chronological precision (e.g. Giesecke et al., 2014). Consequently the role of pollen archives has expanded, as various efforts have concentrated on providing multi-archive, increasingly large-scale land cover narratives via a variety of statistical methods. In Europe, the development of a shared fossil pollen database (European Pollen Database, Leydet 2007-2013; Fyfe et al., 2009) and modern pollen database (Davis et al., 2013), and pan-regionally relevant pollen indices, constitute important advances (Fyfe et al. 2018; Woodbridge et al. 2018). Land cover reconstruction methods such as pseudo-biomization (Fyfe et al., 2010), REVEALS (Sugita, 2007; Trondman et al. 2015) or Plant Functional Types (Davis et al., 2015) have also provided important new approaches, with good overall agreement for temperate and boreal Europe in terms of when and where forest cover was cleared to make way for fields and pastures (Roberts et al. 2018). While pollen analysis is less easily applied in some very dry areas of the Mediterranean (e.g. the Libyan desert) it remains the most widely available means of reconstructing past Mediterranean land cover, and the promising start at integrated land cover assessments in more northerly regions offers the possibility that these or similar approaches might also be used for reconstructing the history of Mediterranean landscapes as well.

That said, the pollen taxa that provide clear indicators of anthropic activity in temperate Europe may not carry the same meaning for Mediterranean landscapes, so there has been a pressing need to establish a new, different set of land cover classes that is more relevant to the latter region's vegetation communities (such as *maquis-garrigue* or olive groves: Fyfe et al. 2015). For this and in the regional papers that follow, we have used cluster analysis of all modern and fossil Mediterranean pollen samples to generate 16 coherent groupings of plant taxa (Fyfe et al. 2018; Woodbridge et al. 2018), whilst also exploring the insights provided by a number of pollen indices that group together related taxa, such as tree crops (*Olea, Juglans, Castanea* or OJC, sometimes also joined by *Vitis*, OJCV). Most of the pollen data used by subsequent papers in this special issue come from 177 sequences archived in the European Pollen Database (EPD; Leydet 2007-2013) for which good age-depth chronologies have already been established (Giesecke et al. 2014). For specific case study regions, these have been supplemented by 76 additional records (listed individually for each case study region paper), that have both been harmonised taxonomically and where necessary given new or re-assessed age-depth models. This resulted in a total of 253 fossil pollen records summed into 200-year time windows for the duration of the Holocene and 1798 modern pollen sites.

Radiocarbon Dates and Settlement Surveys

One major academic shift in archaeology over the last decade has been an increased willingness to address the crucial, but enduringly difficult, challenge of reconstructing pre- and proto-historic population trends in a statistically-useful way. Two methods that have been increasingly prioritised involve collection and analysis of cross-regional aggregations of (a) radiocarbon dates and (b) settlement surveys. The first of these approaches usually involves the summing of large groups of anthropogenic radiocarbon dates, under the assumption that a sufficiently big sample will exhibit highs and lows in date frequency in step with varying intensity of human activity through time, and hence can be thought of as a high chronological resolution proxy for long-term population dynamics. While the basic technique has a deeper pedigree going back three decades (Rick 1987), it has seen far greater emphasis over the last 5-10 years, especially with regard to more refined statistical modelling and testing. For example, the approach has been successfully applied to later prehistoric Europe north of the Alps (Shennan et al. 2013), revealing striking patterns of demographic boom associated with the first Neolithic farming communities, sometimes followed by subsequent population collapse. Further comparison of these summed radiocarbon results with aggregated pollen records has revealed what, on the whole, are excellent matches between the changes exhibited by these two kinds of archive through time (British Isles: Woodbridge et al. 2014, southern Germany: Lechterbeck et al. 2014). This kind of cross-disciplinary synthesis offers huge potential, we would argue, for understanding whole socio-ecological trajectories of Holocene population and land cover change.

A second popular demographic proxy involves systematic synthesis of what we know about past settlement from archaeological surface survey projects and excavations. Archaeological sites have been mapped, dated and counted for many years, but what has changed more recently has been the availability of larger datasets deriving from multiple sources (both intensive systematic surveys and more extensive reconnaissance or site gazetteers), better statistical handling of geographic biases and greater attention to the modelling of chronological uncertainty (e.g. Palmisano et al., 2017). Wherever available, the basic information collected in this manner comprises settlement numbers, locations and sizes, with each site's traditional attribution to a particular cultural period (of varying length) converted to approximate absolute chronology so that the results are most closely-comparable with the summed radiocarbon probability distributions.

As with pollen samples, numbers are similarly large for archaeological data, with >20,000 radiocarbon dates from excavated Mediterranean archaeological sites, and tens of thousands of settlements recorded by systematic regional survey data sets (~30,000). The analysis of these large-scale spatial and temporal datasets has necessarily also involved a combination of GIS, multivariate generalisation, Monte Carlo simulation and probability-based statistical techniques, as well as considerable effort at data harmonisation.

Proxies for Climate, Fire and Erosion

Beyond the core evidence contributed by palynology and archaeology (discussed above), this special issue has also provided an opportunity to elicit up-to-date reconstructions of Mediterranean hydro-climate, fire and erosion regimes. While pollen data have been used by some authors to reconstruct Holocene climate changes in the Mediterranean (e.g. Guiot and Kaniewski 2015), there is a risk of circular reasoning in using the same source of information to establish both potential cause (climate) and consequence (land cover). Fortunately, there exist proxy records of Mediterranean climatic change from data sources other than pollen, such as stalagmite and lake sediment stable isotopes, which are amenable to synthesis and statistical transformation (Finné et al. 2011, Luterbacher et al. 2012; Labuhn et al. 2018). This climatic evidence needs to be critically evaluated alongside human agency in the interpretation of results concerning land cover change. Another significant agency in the summer-dry Mediterranean is wildfire, which can be influenced by both climate and human activities. Long-term trends in fire frequency and intensity can be revealed through charcoal records, especially from micro-charcoal particles that are often identified and counted on pollen slides (Vannière et al. 2011). One of the main consequences of land cover change has been altered erosion and hydrological regimes, which can be reconstructed from geomorphological records of sediment flux and river flooding/sedimentation. There are good proxy data for these from Mediterranean valleys and lake basins (e.g. Macklin and Woodward 2009; Dusar et al., 2011; Benito et al. 2015), some of which have been subject to similar statistical methods to those used in archaeology (e.g. on aggregations of radiocarbon dates).

3. Paper Overviews

The twelve papers that follow in this special issue offer a mix of regional case studies and pan-regional reflection. The seven case study regions have been selected not only in order to provide good geographical coverage over the Mediterranean basin as a whole, but also maximise dense, high quality overlap between well-published palynological and archaeological records. In terms of spatial coverage, the case study regions extend from the Levant in the east to Iberia and Morocco in the west, and without implying any rigid *ex oriente lux* history for the basin, this also allows assessment of the chronologically staged impact from east to west of expanding cultural practices such farming, olive and vine cultivation or complex states.

Regional Case Studies

Palmisano et al. (this issue) consider the south-central Levantine region, in many ways the precocious child amongst these regional cases studies with the impact of such things as equids, sailing ships, olive and vine cultivation, urbanism all occurring earlier than in other study regions, as well as a particularly dense settlement record to make use of. Woodbridge et al. (this issue) address a portion of southern Anatolia which brings together a strong set of pollen archives, considerable wider environmental work and several archaeological surveys, in an area that is particularly relevant for understanding how farming moved into Europe. Weiberg et al. (this issue) consider Greece over a period spanning the earliest European Neolithic colonisations, the appearance of Europe's first palatial, Bronze Age societies and the emergence of Classical Greece, with opportunities for comparing northern and south Greek trajectories across a balanced set of settlement, radiocarbon and pollen evidence. Stoddart et al. (this issue) consider the crucible of cultural change in central western Italy, with a scope that stretches back to the later Mesolithic as in other papers but with a forward eye on dynamics that would eventually produce Rome, a pre-modern city of perhaps a million inhabitants and the heart of an empire whose environmental footprint was enormous. Berger et al. (this issue) analyse an unusually data-rich case study region in southern France with its large sets of radiocarbon dates and many pollen archives, as well as a mix of settlement data from developer-led rescue archaeology, research-led intensive field surveys and sub-surface information from trainline transects. Fyfe et al.'s study (this issue) of eastern Spanish patterns is blessed by a good set of pollen archives, and an opportunity to compare mainland coastal environment trajectories with those pertaining in the more belatedly colonised habitats of the Balearic Islands.

In contrast to these six case studies from the northern coasts of the Mediterranean, one of the most widely-agreed deficiencies in our current understanding of Mediterranean cultural and environmental dynamics relates to the far more limited evidence currently available for the southern side of the sea (e.g. Broodbank 2013: 36-39), with a dearth of pollen studies from most of North Africa, very little radiocarbon sampling from Holocene archaeological sites and patchier archaeological investigation outside Egypt. Such problems can only truly be solved by intensified attention and better-funded work in these southern regions, but it is nevertheless very welcome to be able to add a seventh case study from Morocco that offers a more tentative but important first impression (Cheddadi et al. this issue).

Pan-Mediterranean challenges

Beyond these regional case studies, other issue contributors take the chance to address some key pan-Mediterranean challenges whose results intersect in important ways with the demographic and land cover evidence. Mercuri et al. (this issue), grapple with the methodological challenges of synthesising on-site palynological and anthracological data and thereby provide a much-need counterpoint to the evidence from off-site Mediterranean archives. Finné et al. (this issue) likewise contribute a significant methodological scaffold by using standardised scores to combine Mediterranean palaeoclimatological records, with results that are not only interesting in their own right but also better support ongoing comparative work and which reveal significant regional differences in climate histories. Walsh et al. (this issue) summarise and interrogate trends in erosion as preserved in Mediterranean sedimentary archives, thereby providing an important and complementary view of landscape change to land cover focused perspectives of palynology. Connor et al. (this issue) explore fire regimes as manifest in the natural and anthropogenic charcoal records of the Mediterranean, specifically in Iberia, with obvious wider relevance in terms of how changing fire intensities correlate with climate change and/or human action. Langgut et al. (this issue) bring together what we currently know about the chronology and geographical patterning of olive domestication, a key economically-important tree crop, and ensuing cultivation across the entire basin, with fresh focus on palynological evidence, but also due attention to how this compares with genetic studies and archaeobotanical remains.

In a final paper, Roberts et al. (this issue) step back and offer a first reflection on what kind of joined-up story of all these contributions might offer, with a view also to future research directions. Without anticipating the results of the individual studies that follow, one cross-cutting feature of these studies is the way they provide complementary perspectives on Mediterranean landscapes being shaped by increasingly-coupled, natural and anthropogenic, regimes as the Holocene progressed. More generally, the fact that longitudinal results from Mediterranean environmental science, archaeology and landscape history can be juxtaposed as they are in this issue, in both consensual and adversarial ways, bodes extremely well for future efforts to describe the changing face of this ecologically-striking and culturally-consequential part of the world.

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References

Aranda Jiménez, G, Lozano Medina, A. and Sánchez Romero, M. 2015. *CronoloGEA. Base de datos de dataciones radiocarbónicas del sur de la Península Ibérica*. Available at: www.webgea.es/dataciones/ (accessed 01/05/2018)

Balsera, V, Aubán, J.B, Costa-Caramé, M, Díaz-del-Río, P, García Sanjuán, L and Pardo, S (2015a). The radiocarbon chronology of southern Spain's late prehistory (5600–1000 cal BC): a comparative review. *Oxford Journal of Archaeology* 34, 139-156.

Balsera, V, Díaz-del-Río, P, Gilman, A, Uriarte, A and Vicent, JM (2015b) Approaching the demography of late prehistoric Iberia through summed calibrated date probability distributions (7000-2000 cal BC). *Quaternary International* 386, 208-211.

Barker, G and Mattingly, D (1999-2001 eds.) *The Archaeology of Mediterranean Landscapes*. Oxford: Oxbow Books

Benito G, Macklin, MG, Zielhofer, C, Jones, AF and Machado, MJ (2015) Holocene flooding and climate change in the Mediterranean. *Catena* 130 (Supplement C): 13–33.

Benz, M (2017) *PPND - The Platform for Neolithic Radiocarbon Dates*. Available at:

Available at: https://www.exoriente.org/associated_projects/ppnd.php

Bevan, A and Conolly, J (2013) *Mediterranean Islands, Fragile Communities and Persistent Landscapes: Antikythera in Long-term Perspective*, Cambridge: Cambridge University Press.

Brami M and Zanotti A (2015) Modelling the initial expansion of the Neolithic out of Anatolia. *Documenta Praehistorica* 42: 103. DOI: 10.4312/dp.42.6.

Broodbank, C (2013) *The Making of the Middle Sea: A History of the Mediterranean from the Beginning to the Emergence of the Classical World*. Thames and Hudson.

Butzer, KW (2005) Environmental history in the Mediterranean world: cross-disciplinary investigation of cause-and-effect for degradation and soil erosion. J. Arch. Sci. 32, 1773-1800.

Collins, PM, Davis, BAS and Kaplan, JO (2012) The mid-Holocene vegetation of the Mediterranean region and southern Europe, and comparison with the present day. J. Biogeogr. 39, 1848–1861.

CDRC (2016) Banadora (*BAnque NAtionale de DOnn.es RAdiocarbone pour l'Europe et le Proche Orient. Centre de Datation par le Radiocarbone de Lyon* (CDRC). Available at: http://www.arar.mom.fr/banadora/ (accessed 31 May 2018).

Davis BAS, Zanon M, Collins P, et al. (2013) The European modern pollen database (EMPD) project. *Vegetation History and Archaeobotany* 22: 521-530.

Davis BAS, Collins PM and Kaplan JO (2015) The age and post-glacial development of the modern European vegetation: a plant functional approach based on pollen data, *Vegetation History and Archaeobotany* 24, 303-317.

Dusar, B et al (2011) Holocene environmental change and its impact on sediment dynamics in the Eastern Mediterranean, *Earth Science Reviews* 108, 137-157.

Finné, M, et al (2011) Climate in the eastern Mediterranean, and adjacent regions, during the past 6000 years – a review. *J. Arch. Sci.* 38: 3153-3173.

Frenzel, B (1994 ed.) Evaluation of Land Surfaces Cleared from Forests in the Mediterranean Region during the Time of the Roman Empire, Frankfurt am Main.
Fyfe, RM et al 2009 The European Pollen Database: past efforts and current activities. *Veg. Hist. Archaeobot.* 18, 417-424.

Fyfe, R, Roberts, N and Woodbridge, J (2010) A pollen-based pseudo-biomisation approach to anthropogenic land cover change. *Holocene* 20, 1165–1171.

Fyfe RM, Woodbridge J, Roberts CN (2015) From forest to farmland: pollen-inferred land cover change across Europe using the pseudobiomization approach. Glob Chang Biol 21(3):1,197–1,212

Fyfe, R, Woodbridge, J and Roberts, CN (2018) Trajectories of change in Mediterranean Holocene vegetation through classification of pollen data. Vegetation History and Archaeobotany 27: 351-364; DOI 10.1007/s00334-017-0657-4

Giesecke T, Davis B, Brewer B et al. (2014) Towards mapping the late Quaternary vegetation change of Europe. *Vegetation History and Archaeobotany*, 23, 75–86.

Grove, AT and Rackham, O (2001) *The Nature of Mediterranean Europe. An Ecological History*. Yale UP.

Guiot, J and Kaniewski, D (2015) The Mediterranean Basin and Southern Europe in a warmer world: what can we learn from the past? *Frontiers in Earth Science*, *3*, p.28.

Hinz M, Furholt M, Müller J, et al. (2012) RADON - Radiocarbon dates online 2012. Central European database of 14C dates for the Neolithic and the Early Bronze Age. *Journal of Neolithic Archaeology* 14. DOI: 10.12766/jna.2012.65. Available at: http://radon.ufg.uni-kiel.de/ (accessed 01/05/2018)

Horden, P and Purcell, N (2000) *The Corrupting Sea: a Study of Mediterranean History*. Blackwell.

Jalut, G et al. 2009 Holocene circum-Mediterranean vegetation changes: Climate forcing and human impact. *Quaternary International* 200. 4-18.

Labuhn, I., Finné, M., Izdebski, A., Roberts, N. and Woodbridge, J. (2018) Climatic changes and their impacts in the Mediterranean during the first millennium CE. In: Izdebski, A. and Mulryan, M. (eds) Environment and Society in the Long Late Antiquity (Late Antique Archaeology 12, Leiden), pp. 65–88.

Lechterbeck, J., Edinborough, K., Kerig, T., Fyfe, R., Roberts, C.N. and Shennan, S. (2014) Is Neolithic land use correlated with demography? An evaluation of pollen derived land cover and radiocarbon inferred demographic change from Central Europe. Holocene 24, 1297-1307

Leydet, M (2007-2013) *The European Pollen Database.* (Available at: http://www.europeanpollendatabase.net/).

Lillios, KT, Blanco-González, A, Drake, BL and López-Sáez, J.A. 2016. Mid-late Holocene climate, demography, and cultural dynamics in Iberia: a multi-proxy approach. *Quaternary Science Reviews* 135, 138-153.

Luterbacher, J., Roberts, N. et al. 2012 A review of 2000 years of paleoclimatic evidence in the Mediterranean. In: Lionello, P. (Ed.), The Climate of the Mediterranean region: From the Past to the Future. Elsevier, Amsterdam, pp. 87-185.

Macklin, M and Woodward, J (2009) River systems and environmental change. In Woodward. J. (ed.) *The Physical Geography of the Mediterranean*. Oxford UP. pp. 319-352.

Manning K, Timpson A, Colledge S, et al. (2015) The Cultural Evolution of Neolithic Europe. EUROEVOL Dataset. Available at: http://discovery.ucl.ac.uk/1469811/ (accessed 31 May 2018).

Martínez, PVC, Suriñach, SG, Marcén, PG, Lull, V, Pérez, RM and Herrada, CR (1997) Radiocarbon dating and the prehistory of the Balearic Islands. *Proceedings of the Prehistoric Society* 63, 55-86.

Manen, C and Sabatier, P (2003) Chronique radiocarbone de la néolithisation en Méditerranée nord occidentale, *Bulletin de la Société Préhistorique Française* 100, 479-504.

Oms, FX, Martín, A, Esteve, X, Mestres, J, Morell, B, Subirà, ME and Gibaja, JF (2016) The Neolithic in Northeast Iberia: Chronocultural Phases and 14C. *Radiocarbon* 58, 291-309.

ORAU (2016) *Oxford Radiocarbon Accelerator Unit (ORAU) database*. Available at: https://c14.arch.ox.ac.uk/.

Palmisano A, Bevan A and Shennan S (2017) Comparing archaeological proxies for long-term population patterns: An example from central Italy. Journal of Archaeological Science 87: 59–72. DOI: 10.1016/j.jas.2017.10.001.

Paulsson, B (2017) *Time and Stone. The Emergence and Development of Megaliths and Megalithic Societies in Europe*. Oxford: Archaeopress.

Reingruber A and Thissen L (2005) 14C database for the Aegean catchment (Eastern Greece, southern Balkans and western Turkey) 10,000–5500 cal BC. In: Lichter C and Meri. R (eds) *How did farming reach Europe?: Anatolian-European relations from the second half of the 7th through the first half of the 6th millennium cal BC : proceedings of the International Workshop, Istanbul, 20-22 May 2004*. Byzas 2. Đstanbul: Ege Yayınları, pp. 295–327.

Reingruber A and Thissen L (2016) The 14SEA Project. A 14C database for Southeast Europe and Anatolia (10,000–3000 calBC). Available at: http://www.14sea.org/2_dates.html (accessed 31/05/2018).

Rick, JW (1987) Dates as data: an examination of the Peruvian Preceramic radiocarbon record, *American Antiquity* 52.1: 55-73.

Roberts, N, Fyfe, RM, Woodbridge, J, Gaillard, M-J, Davis, BAS, Kaplan, JO, Marquer, L, Mazier, F, Nielsen, AB, Sugita, S, Trondman, A-K and Leydet, M (2018). Europe's lost forests: a pollen-based synthesis for the last 11,000 years. *Scientific Reports* 8.716. DOI:10.1038/s41598-017-18646-7

Shennan, S et al. (2013) Regional population collapse following initial agriculture booms in mid-Holocene Europe. *Nature Communications*, DOI 10.1038/ncomms3486

Sugita S (2007) Theory of quantitative reconstruction of vegetation I. Pollen from large sites REVEALS regional vegetation. *The Holocene*, 17, 229–241.

Trondman A-K, Gaillard M-J, Sugita S et al. (2015) Pollen-based land-cover reconstructions for the study of past vegetation-climate interactions in NW Europe at 0.2 k, 0.5 k, 3 k and 6 k years before present. *Global Change Biology*, 21: 676-697.

Vannière B, Power M, Roberts N, Tinner W, Carrión J, Magny M, Bartlein P et al. (2011) Circum-Mediterranean fire activity and climate changes during the mid Holocene environmental transition (8500- 2500 cal yr BP). *The Holocene* 21: 53-73

Van Strydonck, M and De Roock, E (2011) Royal Institute for Cultural Heritage Web-Based Radiocarbon Database, *Radiocarbon* 53.2: 367-370. Available at: http://c14.kikirpa.be/ and http://radiocarbon.kikirpa.be/

Vermeersch, PM (2017) *Radiocarbon Palaeolithic Europe Database. Version 23*. Available at: https://ees.kuleuven.be/geography/projects/14c-palaeolithic/ (accessed 31/05/2018).

Walsh, K (2014) *Mediterranean Landscape Archaeology: An environmental perspective*, Cambridge: Cambridge University Press.

Weninger B, Edinborough K, Bradtmuller M, et al. (2009) A radiocarbon database for the Mesolithic and early Neolithic in Northwest Europe. In: Cromb. P, Strydonck M, Sergant J, et al. (eds) *Chronology and evolution within the Mesolithic of North-West Europe*. Cambridge: Cambridge Scholars, pp. 143–176.

Woodbridge J, Fyfe RM, Roberts N, Downey S, Edinborough K and Shennan S (2014) The impact of the Neolithic agricultural transition in Britain: a comparison of pollen-based land-cover and archaeological ^{14}C date-inferred population change. *J. Arch. Sci.* 51, 216-224.

Woodbridge, J, Roberts, N and Fyfe, J (2018) Pan-Mediterranean Holocene vegetation and land-cover dynamics from synthesised pollen data, *Journal of Biogeography* 45, 2159-2174.