Quaternary International 393 (2016) 19–23

Contents lists available at ScienceDirect

Quaternary International

journal homepage: www.elsevier.com/locate/quaint

Modelling human presence and environmental dynamics during the Mid-Pleistocene Revolution: New approaches and tools

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A R T I C L E I N F O

Article history:
Available online 28 June 2015

Keywords:
Europe
Formal models
Palaeoecology
Human settlement
Cultural evolution

A B S T R A C T

Drastic changes, driven by variations in orbital forcing, occurred in the Earth's climate system around 1.0 Ma. As a consequence, a marked reorganization of the ecosystems took place in Europe between 1.2 and 0.6 Ma. Arrival of hominins to Western Eurasia occurred at this time or slightly earlier, and many questions related to their time and mode of arrival, their survival opportunities, their distribution across Europe and their cultural evolution, remain unsolved. We present here a research project supported by the INQUA Human and Biosphere Commission aimed to address the ecological and behavioural dynamics of hominin populations in Western Europe during the late Early and the early Middle Pleistocene. The project emphasises the use of formal modelling approaches to test specific hypotheses about the causal mechanisms promoting variation in the distribution and behaviour of those ancient human populations.

1. Introduction

Presence of human populations in Europe at the end of the Early Pleistocene is currently a widely documented fact (Moncel, 2010; Allué et al., 2013; Mosquera et al., 2013), although the exact time of the arrival of humans to Europe is still under debate. Although a body of evidence (absolute dating, magnetostratigraphical and biochronological correlations) confirms that between about 1.4 and 1.1 Ma archaic human groups were present in Southern Europe (see e.g. Arzarello et al., 2007; Bermúdez de Castro and Martinón-Torres, 2013; Parés et al., 2013; Toro-Moyano et al., 2013; Lozano-Fernández et al., 2014; López-García et al., 2015; Palmqvist et al., 2015), this fact was recently questioned by Muttoni et al. (2013, 2015), who stated that “evidence of hominin presence in Europe before the Jaramillo (>1 Ma), … is … very tenuous and frequently based on problematic ESR dating” (Muttoni et al., 2013, 748). However, Rodriguez et al. (2015) recently showed that human presence in Europe at the end of the Early Pleistocene cannot be considered scarce, in comparison with the abundance of other large mammals, particularly carnivores, during the same period. A diffusion into Central Europe at the time of the Jaramillo event (Untermassfeld, Germany; Landeck, 2010; Garcia et al., 2013) is also under debate (Baales, 2014), while strong evidence demonstrates that *Homo* was able to colonize northern Europe shortly after the Matuyama/Brunhes boundary as evidenced by the sites of Happisburgh (Parfitt et al., 2010; but see also; Westaway, 2011), and Pakefield (Parfitt et al., 2005). However, the number of sites with evidence of human presence in Europe during the subsequent period (0.7–0.5 Ma) is scarce, leading some authors to propose a depopulation of the continent during that time interval (Moncel et al., 2013; Mosquera et al., 2013).

The question arises whether a hominin presence was continuous during the Early Pleistocene (in the face of dramatic changes of climate, environment and mammalian palaeocommunities), or whether multiple dispersal events occurred, perhaps originating from a source population persistently inhabiting the West or South-West Asia (see e.g. Bermúdez de Castro and Martinón-Torres, 2013; Bermúdez de Castro et al., 2013 for a discussion).

Moreover, although the artefacts recovered from most archaeological sites younger than 0.6 Ma have generally been attributed to Oldowan technological complexes or Mode 1, the discovery of Large Cutting Tools (LCTs) at the late Early Pleistocene site of Barranc de la Boella (Vallverdú et al., 2014), and La Noira, dated to the beginning of the Middle Pleistocene (Moncel et al., 2013), suggest that Mode 2 was already present in Europe at the transition from Early to Middle

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http://dx.doi.org/10.1016/j.quaint.2015.06.003
1040-6182/

Pleistocene. An Early Pleistocene age has also been claimed for the Mode 2 artefacts from Solana del Zamborino (Scott et al., 2007), but this site is actually Middle Pleistocene (Jiménez-Arenas et al., 2011). The presence of Acheulean tool types in Early Pleistocene deposits of southern Europe challenges the long lasting concept that in the European Early Palaeolithic, Mode 1 technology (seen as a prerogative of *Homo* sp. and *H. antecessor* humans) predates the appearance of Mode 2 technology of *H. heidelbergensis* (Jiménez-Arenas et al., 2011). The latter was widespread over Western Europe from 0.5 to 0.3 Ma although, surprisingly, Mode 2 complexes were absent from Eastern Europe (Doronichev, 2010). Accordingly, a second question arises whether a discontinuity existed in Europe between Mode 1 and Mode 2 technologies and these cultural changes were paralleled by a replacement of the hominin species inhabiting Europe, i.e. the disappearance of *Homo antecessor* and the eventual appearance of *Homo heidelbergensis* at 0.5 Ma (Hublin, 2009; Condemi and Weniger, 2011; Manzi, 2011; Stringer, 2012). With these data in mind, a complex scenario arises for the early colonization of the continent, with phenomena such as dispersal events, replacements of species and abandonment of territories with unfavourable conditions for human colonization playing a significant role.

2. A strategic guide to examine the interactions between humans and shifting environments

Interestingly, the complex history of human colonization in Europe was marked by a period of drastic climatic changes, driven by variations in orbital forcing, known as the Mid-Pleistocene Revolution (MPR), promoting a marked environmental instability from about 1.2 to 0.6 Ma, particularly evident from the time of the Jaramillo submagnetochron to the end of the Early Pleistocene, when the frequency of Glacial–Interglacial oscillations became less stable, amplitudes increased, with melting periods lasting significantly less than anaglacial phases (Head and Gibbard, 2005; Maslin and Ridgwell, 2005). This transition in the climate system promoted the expansion of more open environments and trigged a reorganization of the European ecosystems (Palombo et al., 2005; Suc and Popescu, 2005; Bertini et al., 2010; Croitor and Brugal, 2010; Kahlke et al., 2011; Leroy et al., 2011; Palombo, 2014a). A comparison of the vegetation and faunal records in SW Europe indicates that both vegetation and animal communities significantly varied during the MPR, though the timing and extent of the changes were different and varied across the studied region (Magri and Palombo, 2013). Those environmental changes likely affected the survival opportunities of the European humans, not only because the rather unpredictable climatic changes they had to cope with, but also because the new environments provided different qualities and quantities of trophic resources. The profoundly rearranged large mammal communities offered to hominins a renewed spectrum of potential prey and competitors (Kahlke et al., 2011; Palombo, 2014a). Moreover, the new ecosystems, dominated by more open environments, also altered the amount and quality of vegetable resources available to those early hunter–gatherer populations. All these changes could have affected human populations in different ways. Climate factors, temperature in particular, are major constraints for the distribution of any organism, and hominins are not an exception, especially because there is no evidence for the use of fire in Europe older than 500 ka, and its use is not generalized until about 250 ka (deLumley, 2006; Roebrooks and Villa, 2011; Mosquera et al., 2013). The faunal reconfiguration during the MPR involved a significant increase in the body size of potential prey, the extinction of several species that were presumably competitors for hominins and the arrival of other ones (Croitor and Brugal, 2010; Rodríguez et al., 2012; Palombo, 2014a). The body size rearrangement in the guild of primary consumers was not trivial for hominins because, generally speaking, it is not a simple task for predators to subdue and kill large herbivores. However, given its highly adaptive behavior, hominins may have developed new strategies to take advantage of these new trophic resources. Alternatively, reorganization of the carnivore guild may have trigged corresponding shifts in hominin behavior. In order to test the consequences of both of the alternative hypotheses in the archaeological record, it is required to develop formalized models for the respective behavioral responses. However, as we will see below, quantitative descriptive models allow us to evaluate the feasibility of several competing hypotheses. Validating alternative models include test whether the archaeological record is compatible with the parameters specified and predicted by the models themselves.

Although most scholars will agree that environmental changes affected human survival and distribution in Europe, it is not well established how, where, when and to what extent the environment affected human population dynamics. The study of such complex phenomena requires the contribution and cooperation of researchers from several fields. During the last decades, palaeontologists, palaeoanthropologists and archaeologists have produced spatio-temporal and taxonomically organized datasets describing hominin distribution. In parallel, several conceptual models have been proposed to explain the dynamics of the human colonization of Europe in this period (Palombo, 2010; Bermúdez de Castro and Martinón-Torres, 2013; Dennell et al., 2011; Mosquera et al., 2013; O'Regan et al., 2014), but often they reflect the actual data only loosely or are only based on data provided from a specific research field. It becomes increasingly clear that complex questions, like understanding the dynamics of the early colonization of the continent, requires multidisciplinary synergic approaches.

During the last five-year period, the amount and quality of data available for this period has been continuously increasing (Fig. 2). This evidence opens a new window to the use of quantitative methodologies, beyond the traditions of Palaeolithic archaeology or Pleistocene palaeontology. Furthermore, mathematical modelling has revealed itself as an extremely helpful tool to describe complex systems dynamics in other disciplines, but it has been rarely used in terrestrial Quaternary palaeoecology or Palaeolithic archaeology. However, in the relatively few occasions in which the dynamics or eco-dynamics of Palaeolithic humans has been modelled in a formal and/or quantitative way this approach has shown its great potential (Banks et al., 2006, 2008a, 2008b, 2008c; Fernandez et al., 2006; Fernandez and Legendre, 2003; Holmes, 2007; Palombo, 2014b; Rodríguez-Gómez et al., 2014; Rodríguez-Gómez et al., 2013; Romanowska, 2014). The project on "Modelling human settlement, fauna and flora dynamics in Europe during the Mid-Pleistocene Revolution (1.2–0.4 Ma)" funded by the INQUA Human and the Biosphere Commission (HabCom) is a pilot initiative which will be developed into an International Focus Group (IFG) that will be active during the period 2016–2020. This IFG intends to bridge the gap between the researchers interested in understanding the behavioural and ecological dynamics of the first European humans, the specialists on dynamic shifts in ecology and environments, and the people with the skill to build mathematical models developed in order to test hypotheses about the interactions among the different factors (Fig. 1). The key feature of this project is to incorporate researchers from disciplines not directly linked to the study of the Quaternary, like mathematicians, physicists or engineers with experience in the study of complex systems through mathematical modelling. Considering the type of questions the MPR project intends to address, the models to be developed will be descriptive models. Descriptive models are representations of a phenomenon or a complex system that allow the researcher to