Modelling Hominin Population Dynamics: the Case Study of the Movius Line

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Abstract—Proposed over half a century ago, the Movius Line model is one of the most persistent research themes in Early Palaeolithic Archaeology. It describes a robust spatial pattern of the cultural dichotomy between Central and East Asia and Eastern Europe on one side, and Africa, Western Europe and Southwest Asia on the other. Recently, Lycett & Norton [1] argued that in areas further away from the origins of the first ‘Out of Africa’ dispersal the population density was lower than in the zones closer to Eastern Africa. As a result, smaller and less well-connected human groups could not sustain the sophisticated technological knowledge necessary to produce Mode 2 implements and reverted to simpler knapping strategies i.e. Mode 1. This paper presents an Agent-based model developed to test the above hypothesis. It compares population density in the Mode 1 and Mode regions throughout the simulation to evaluate if the proposed demographic disparity between the two regions is plausible. The results show that the dispersal itself is an unlikely candidate for the prime driver behind population dynamics in the Pleistocene. Instead, research should focus more on other potential factors, in particular the relative carrying capacity.

I. INTRODUCTION

As early as the 1940s Hallam Movius [2], [3] pointed out a robust dichotomy between Lower Palaeolithic lithic industries in Africa and Western Europe, and contemporary assemblages in East Asia. To the south and west of this virtual “Movius Line” the Palaeolithic record is dominated by the Acheulean (Mode 2) industry while in Eastern Europe, Central and East Asia most of lithic assemblages belong to the Oldowan (Mode 1). A number of hypotheses have been proposed to explain this spatio-cultural pattern including differences in cognitive abilities of Asian, European and African hominins, raw material types and availability or cultural tradition to name just a few [4]-[8].

Recently, Lycett and Norton [1] argued that the fragmentation of human populations caused by the first ‘Out of Africa’ dispersal disrupted social learning mechanisms and led to a cultural loss of more sophisticated technologies among the groups living further away from the dispersal’s point of origin. This model looks plausible given our current knowledge, however, as the authors note: “What is now urgently needed are more sophisticated means than we have provided here of assessing Pleistocene demographic parameters in the key regions east and west of the Movius Line s.l.” [1: 62].

The aim of this study is to simulate the first ‘Out of Africa’ dispersal and compare population densities in the Acheulean and Oldowan regions throughout the simulation to evaluate if the proposed demographic disparity between the two regions is plausible.

II. MATERIALS AND METHODS

Computational modelling provides a unique opportunity to confront some of archaeology’s most pressing research questions. It allows to overcome some of the limitations of traditional conceptual methods and intrinsic biases of the archaeological record. Although simulations reflect our current understanding of a given system, they can be built largely independent of the empirical data as a form of ‘virtual lab’, ‘thought experiment’ or ‘generative social science’ [9]-[12]. Equally, this method helps to tackle the complexity of a given system enabling researchers to move beyond simple conceptual models. Finally, even the formalisation of the proposed hypotheses, necessary for the coding, helps to identify key entities and variables of the system, and opens the door for the application of other quantitative methods.

This simulation is an Agent-based model programmed in Python (v. 3.2). It consists of two main model entities: the agents representing hominin groups and the friction map representing the environment over which they disperse. In more technical terms, the simulation is a three dimensional matrix with each cell corresponding to an area of the friction map and containing a value representing the current number of agents (human groups).

A. Friction Map

A set of maps showing vegetation distribution under ‘hot’, ‘mild’ and ‘cold’ conditions during the Pleistocene (based on: [13]-[15] was coupled with a reconstruction of the coastal areas taking into account the changes in the Pleistocene sea levels. This allowed to model an environmental layer which changes dynamically according
to the actual temperature and sea level curves [16] with each step of the simulation.

B. Agents

The agents followed a simple diffusion algorithm in which, in every time step of the simulation, a certain percentage (dependent on the environment type of the cell in which the agents live) of agents spread into the neighbouring four cells. The number of agents is then updated by multiplying it by the population growth rate and capped to the carrying capacity (both dependent on the environment type of the cell in which the agents live).

III. Parametrisation

The carrying capacity was parameterized with values based on hunter-gatherer population density data collated from over 250 modern groups by Binford [17]. Population growth values were taken from modern and Palaeolithic estimates in [18] while the range of maximum dispersal speeds was given in [19]. Such a wide spectrum of values resulted in testing 24 different scenarios with three axes of parameters: a) maximum dispersal speed (0.25 km and 0.5 km per year); b) population growth (Palaeolithic estimate: 0.001% - 0.003%; Modern hunter gatherer estimate 0.1% - 0.2%) and c) carrying capacity of mobile hunter-gatherer groups (average value and maximum value) as well as average value for non-mobile hunter-gatherer groups. The two latter parameters were varied depending on the environmental zone, so that the carrying capacity and population growth of agents in, for example, tropical forest differed from agents living in the temperate zone etc. The model has no sources of stochasticity and as such the scenarios were run only once.

IV. Results and Discussion

The results are visualised as a series of maps showing the population density of each cell. None of the tested scenarios produced a dichotomy in population density between regions on different sides of the Movius line. Also, the population density did not decrease further away from the point of origins of the ‘Out of Africa’ dispersal as proposed by Lycett and Norton [1]. In contrast, the pattern of population dynamics closely followed the carrying capacity of each environmental zone. Please note that in this model the term ‘carrying capacity’ is understood as the maximum resource (both dependent on the environment type of the cell) the agents live.

This would indicate that the long, feathered distribution of the dispersal front is not plausible and therefore the distance from the point of origin of the first ‘Out of Africa’ is unlikely to be the primary cause of the proposed demographic disparity between the regions on both sides of the Movius line. This does not disprove Lycett and Norton’s cultural transmission model in its entirety but instead shows that the source of the variability of population density could have been related to factors other than the distance from East Africa. The lower relative carrying capacity of environmental zones to which hominins were not optimally adapted to (for example temperate forests) is a prime suspect but other factors, not accounted for in this particular simulations (for example, dependence on social networks), should also be considered.

V. Conclusions

This paper presented an Agent-based model designed to investigate hominin population dynamics in the Early and Middle Pleistocene, and in particular the plausibility of the hypothesis that the form and timing of the ‘Out of Africa’ dispersal might have had an impact on population densities of hominin groups on two sides of the, so-called, Movius line.

The results of multiple scenarios using a wide variety of parameter values derived from ethnographic as well as archaeological data show that this hypothesis is highly implausible given the conditions imposed in this simulation.
Further, it suggests that relative carrying capacity might be a prime factor influencing demographic patterns in the Pleistocene.

Finally, it is worth stressing out that some of the conclusions could have been reached with a ‘pen and paper’ approach (see the discussion section). However, it is only thanks to the formalisation of the model that the dependencies between system’s elements working on diametrically different scales were recognised and quantified. Therefore, this case study showcases the use of computational modelling as a heuristic tool allowing researchers to effectively formalise conceptual models of studied systems, to identify previously unrecognised factors influencing the systems, and to draw robust conclusions despite the sparsity of the available data.

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REFERENCES


