CS6/G8 – Neolithic-Mesolithic space competition in northern Europe

Neus Isern, Joaquim Fort

Introduction

In northern Europe, the Neolithic spread took place at a much slower rate than the average 1km/y. We model this delay in terms of the space competition with Mesolithic populations.

Archaeological evidence

The analysis of a database of 902 dates on the Early Neolithic shows a slowdown of the spread at Northern Europe [1], evidenced qualitatively in the map, Fig. 1, and quantitatively along the area of study in Fig. 2a.

Competition with Mesolithic populations, more numerous in the area (Fig. 2b) [1], may be the cause [2,3].

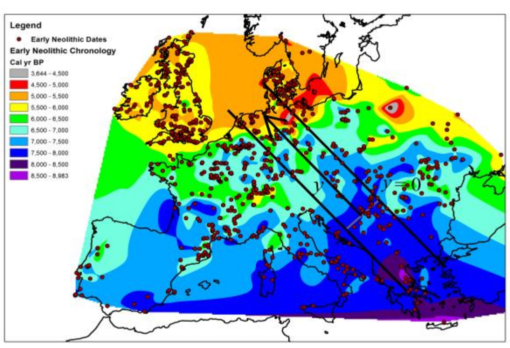

Fig. 1 Neolithic chronology. The region and the arrow on the map delimit the region analyzed. (Source: Fig. 1 in Ref. [1], redrawn)

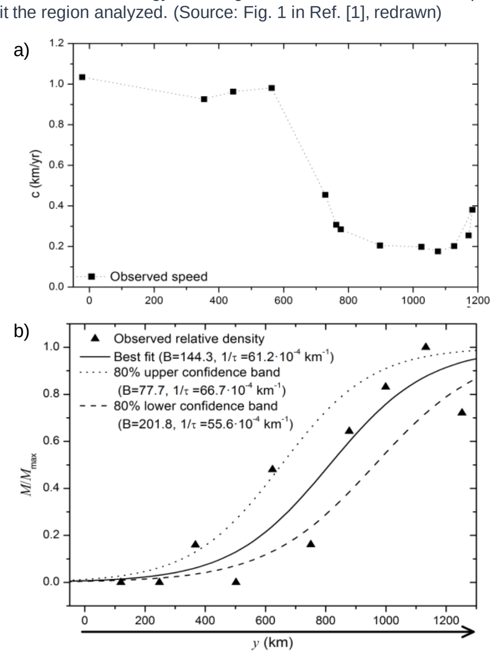

Fig. 2 (a) Speed of the Neolithic spread and (b) relative Mesolithic population density within the region delimited in Fig. 1. and along the arrow direction. (Data from: Fig. 2 in Ref. [1])

Space competition model

The presence of Mesolithic population reduces the free, $s = 1 - M(y)/M_{max}$, and thus the spread dynamics [4].

Hindered dispersion

Non-isotropic kernel to include the difficulty to advance toward populated areas [4].

$$\phi = \frac{\psi(\Delta)}{2\pi}\left[1 - \frac{\partial M/\partial y}{M_{max} - M(y)}\Delta sin\theta\right]$$

Δ: jump distance, θ: jump direction,
$\frac{\psi(\Delta)}{2\pi}$ dispersion kernel in unpopulated space.

Reduced population growth

Modified logistic growth equation to account for the competition for space and resources between the two populations [4]:

$$F = aN\left(1 - \frac{N}{N_{max}} - \frac{M}{M_{max}}\right)$$

a: growth rate

Time-delayed reaction-diffusion equation

We use the new kernel and population growth equation to derive a time-delayed (second-order expansion) reaction diffusion equation [1]:

$$\frac{\partial N}{\partial t} + \frac{T}{2}\frac{\partial^2 N}{\partial t^2} = \left(\tilde{a} + \frac{\tilde{a}^2 T}{2}\right)N$$
$$+D\left(1 + \tilde{a}T + \frac{\tilde{a}^2 T^2}{2}\right)$$
$$\times\left[2\frac{\partial M/\partial y}{M_{max} - M}\frac{\partial N}{\partial y} + \left(\frac{\partial^2 N}{\partial x^2} + \frac{\partial^2 N}{\partial x^2}\right)\right],$$

Where $\tilde{a} = a\left(1 - \frac{M}{M_{max}}\right)$

Front speed

The rate of spread in the direction of the arrow in Fig. 1 is given by [1]:

$$c = \frac{1}{2\tilde{G} - 1}$$
$$\times\left[\left(\tilde{U}_y^2 - [2\tilde{G} - 1]\left[\tilde{U}_y^2 - \frac{4D\tilde{G}(\tilde{G}-1)}{T}\right]\right)^{1/2} + \tilde{U}_y\right],$$

where $\tilde{U}_y = -2D\tilde{G}\frac{\partial M/\partial y}{M_{max} - M}$ and $\tilde{G} = 1 - \tilde{a}T + \frac{\tilde{a}^2 T^2}{2}$.

Results

Using realistic anthropological parameters from pre-industrial farming populations (see Table 1), the predictions obtained from the model are consistent with the slowdown observed, as shown in Figs. 3 and 4.

Table 1 Neolithic anthropological parameter values

Parameter	Mean value	80% CL interval
T	32 y [5]	
$\langle\Delta^2\rangle$	1531 km² [6]	900 – 2200 km² [7]
$D = \langle\Delta^2\rangle/4T$ [5]	11.96 km²/gen [1]	7.03 – 17.19 km²/gen [1]
a	0.028 y⁻¹ [9]	0.023 – 0.033 y⁻¹ [9]

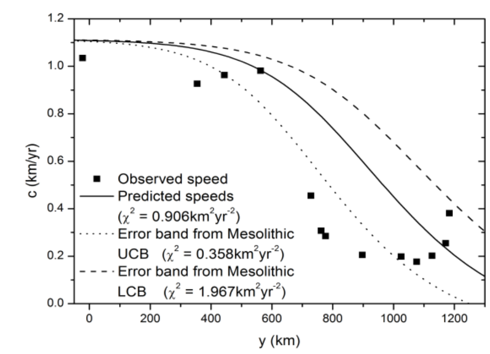

Fig. 3 Observed (symbols) and predicted (lines) front speeds. Results computed from mean values in Table 1, and 80% CL range for the Mesolithic density (Fig 3). (Data from Fig. 2b in Ref. [1].)

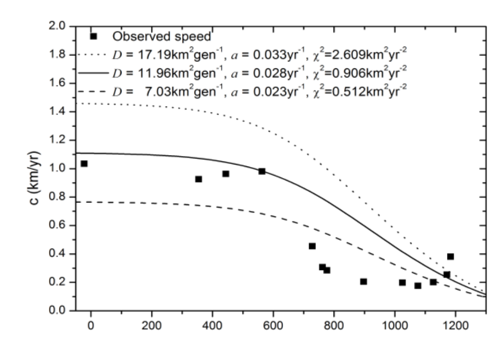

Fig. 4 Parameter sensitivity of the model. Results predicted with the 80% CL intervals in Table 1 and the mean Mesolithic density in Fig 2b. (Source: Fig. 3a in Ref. [1], redrawn.)

Conclusions

We have developed a new reaction-diffusion model with space competition between Neolithic and Mesolithic populations.

The predicted slowdown is consistent the archaeological observations.

The results support the hypothesis that the Mesolithic presence delayed the Neolithic spread in Northern Europe.

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