Archaeo-riddle Analysis

Trying methods to improve archaeological inference

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1 Research Question

RQ3. What was the rate of dispersal of poppy chewers?

2 Approach

The inverse of asking *How did a cultural trait travel?* is to ask *When did it arrive?* The latter captures the approach to exploring poppy chewer movement used here. Using Bayesian phase models [1, 2, 3, 4], accurate estimates of local arrival times within smaller geographic regions are calculated. A hierarchical structure is introduced into the Bayesian phase model, in order to account for an uneven sampling where some sites contribute multiple radiocarbon dates.

A hierarchical Bayesian phase model defines the calendar date $(\theta_{i,j,k})$ and subsequent observed radiocarbon age $(X_{i,j,k})$ of sample i from site j in region k as

$$\theta_{i,j,k} \sim \text{Unif}\left(\alpha_{j,k},\, \alpha_{j,k} + \delta_{j,k}\right) , \tag{2.1}$$

$$\alpha_{j,k} \sim \text{Unif}\left(a_k,\, b_k\right) , \tag{2.2}$$

$$X_{i,j,k} \sim \text{Normal}\left(f\left(\theta_{i,j,k}\right),\, \sigma_{i,j,k}\right) , \tag{2.3}$$

where $\alpha_{j,k}$ is the arrival time of the phenomenon at site j in region k; a_k is the arrival time of the observed phenomenon in region k; the term $(\alpha_{j,k} + \delta_{j,k})$ is the end date at site j in region k ($\delta_{j,k}$ is understood as the duration of occupation); and b_k is the end date in this region. The measurement uncertainty of $\theta_{i,j,k}$ is accounted for by Eq.(2.3), where $\sigma_{i,j,k}$ is the square root of the sum of the squares of the error on the calibration curve and the sample's ^{14}C age error.

3 Strategy to select additional data

Across Rabbithole, 14 rabbit skinner (hunter gatherer) and 25 poppy chewer (farmer) sites in areas 14, 45, 65, 66, 30 had been identified. Participants were given the ability to survey five additional areas of information. In order to decide on the most interesting regions to survey, a friction calculation was performed. The Rabbithole data provided included elevation and environmental fitness information. This information was used in order to calculate an aggregated fitness, F_k for each region k, assuming initial movement from a putative origin region m:

$$F_k = d_{m,k} - \omega_f \times f_k + \omega_e \times e_k , \tag{3.1}$$

where $d_{m,k}$ is the distance between the centre of the origin region m and the centre of the region of interest k; e_k is the mean elevation in region k and f_k is the mean environmental fitness in each region. The magnitude of

the weights (ω_e and ω_f) were chosen to ensure all terms are of the same order of magnitude, while the direction of these weights build in the initial assumptions (i) moving to a lower elevation leads to a decrease in friction and (ii) moving to a higher fitness value leads to a decrease in friction. Note, however, that this was a rough calculation and that there are more sophisticated statistical means of determining the magnitude and direction of these weights.
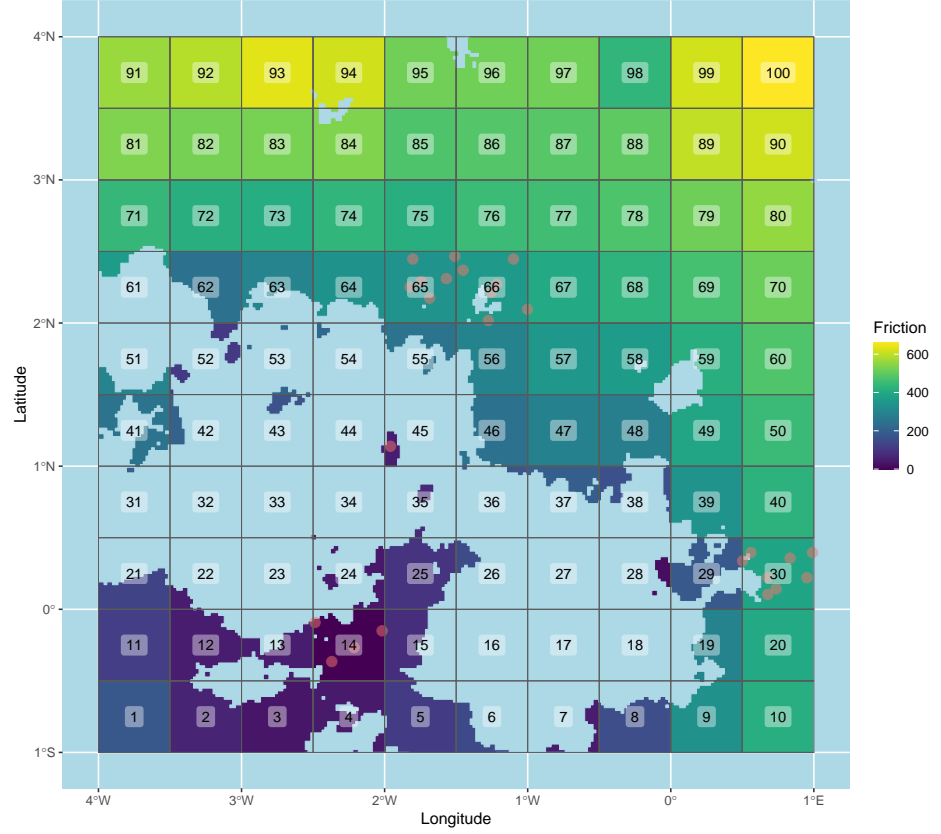

Figure 1: **Aggregated friction**: Aggregated friction, F_k, for each region k in Rabbithole

Examining figure (1), additional information was requested from regions 8, 12, 48, 62, 98. In the final dataset there are 43 poppychewer sites with 206 associated radiocarbon dates and 29 rabbitskinner sites with 60 $C14$ dates.

4 Results

As a first step, a Bayesian quantile regression was performed which yielded a global poppychewer dispersal over the whole of Rabbithole at a rate of 0.9-2.2 km.year^{-1}.
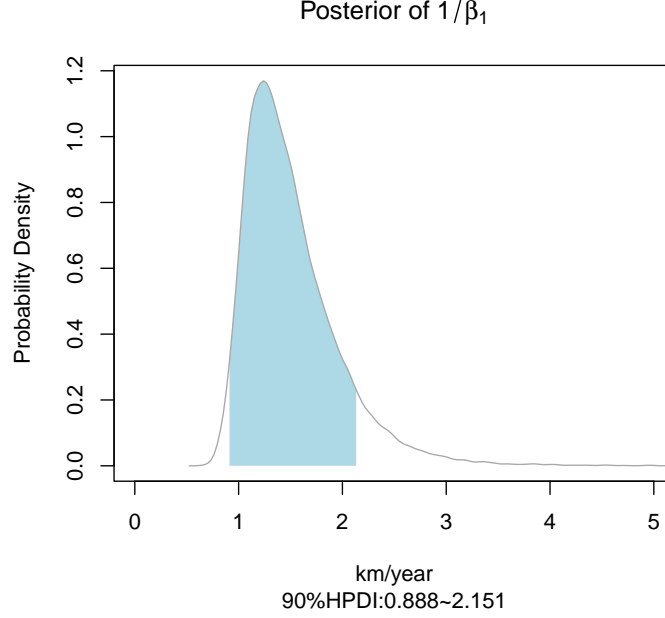

Figure 2: Posterior distribution of the dispersal rate $(1/\beta_1)$ for the spread of poppy chewers (and their associated agricultural subsistence strategy) in Rabbithole using Bayesian quantile regression.

As discussed in section (2), in order to examine local dynamics, a hierarchical Bayesian phase model is used. An MCMC analysis was performed over larger spatial regions (diving Rabbithole into 25 areas). The results are given in figures (3) and (4).
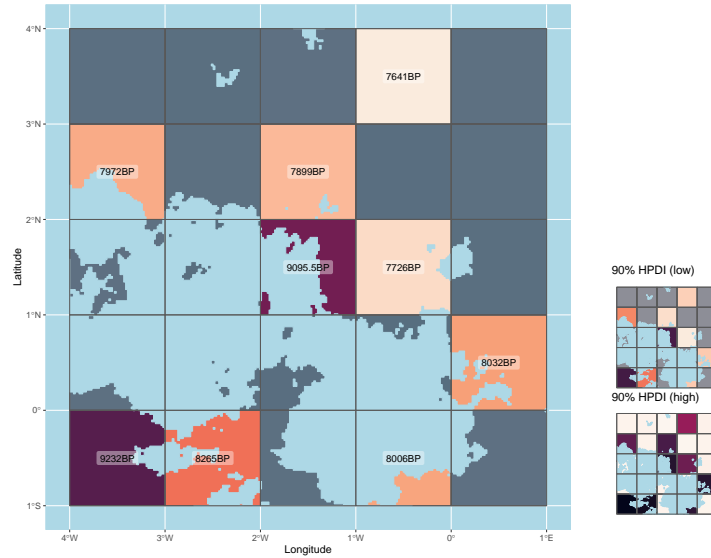

Figure 3: Median arrival times in each region calculated using a hierarchical Bayesian phase model, with low and high bounds of the 90% HPDI indicated in subplots
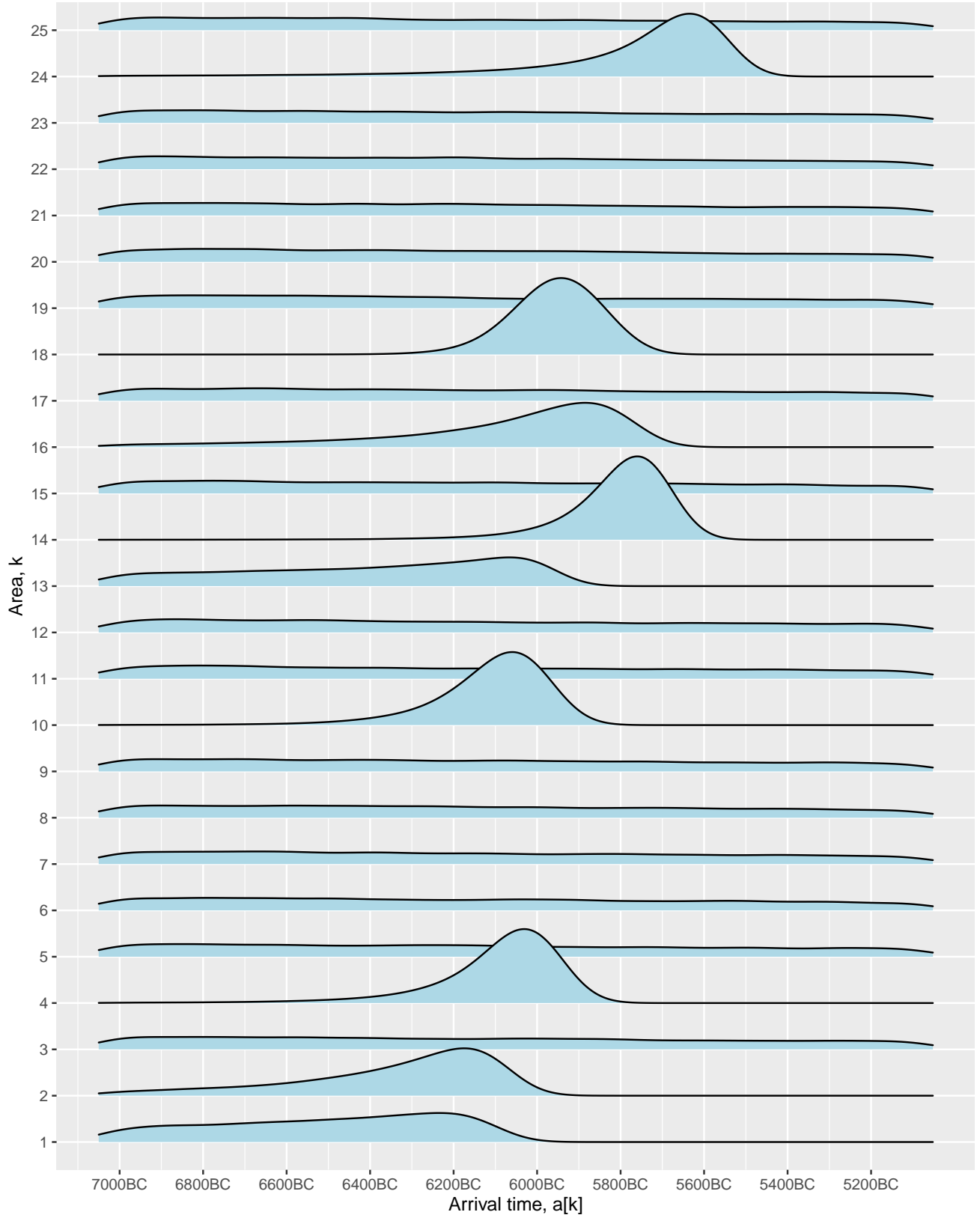
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Figure 4: Posterior distribution of arrival times a_k in region k using a hierarchical Bayesian phase model

References

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