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**Article:**

Sizling, AL, Pokorny, P, Jurickova, L et al. (7 more authors) (2016) Can people change the ecological rules that appear general across space? *Global Ecology and Biogeography*, 25 (9). pp. 1072-1084. ISSN 1466-822X

<https://doi.org/10.1111/geb.12467>

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# Supplementary On Line Materials for

## Can people change the ecological rules that appear general across space?

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### Contents

<b>S1:</b> Data	<b>2</b>
<b>S2:</b> The Similarity Indices	<b>3</b>
<b>S3:</b> $\beta'_{Sim}$ Decays	<b>4</b>
<b>S4:</b> Fitting	<b>5</b>
<b>S5:</b> Residuals in Similarity Indices	<b>7</b>
<b>S6:</b> Sampling Effort	<b>8</b>
<b>S7:</b> Species Richness	<b>8</b>
<b>S8:</b> Tests	<b>9</b>
<b>S9:</b> Tree Cover	<b>14</b>
<b>S10:</b> Species Richness – Temperature Plots	<b>14</b>
<b>S11:</b> $\beta'_{Sim} - S$ – Temperature Relationships	<b>15</b>
<b>S12:</b> Jumps of Jaccard Index	<b>15</b>
<b>S13:</b> Scenario	<b>16</b>
<b>S14:</b> Rates of Distance Decays	<b>16</b>

## S1: Data

**Fossil data:** Plant (pollen) and snail data were taken from the Czech Quaternary Palynological database – PALY CZ (Kuneš *et al.*, 2009) and (Horáčková *et al.*, 2014) respectively. In snails, we followed the procedure of dating, which was used in the pollen database (Blaauw, 2010).

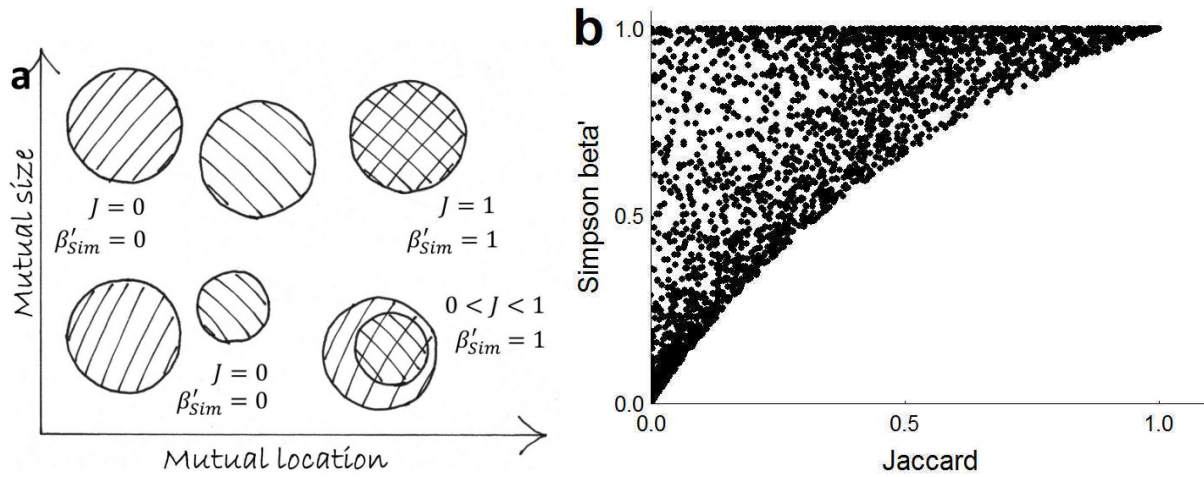
Pollen sites (id from PALY CZ database [http://botany.natur.cuni.cz/palycz/data\\_list.php](http://botany.natur.cuni.cz/palycz/data_list.php)): 1, 3, 5, 9, 10, 11, 14, 15, 17, 18, 23, 24, 25, 27, 28, 29, 31, 32, 36, 38, 40, 41, 42, 43, 44, 46, 47, 48, 49, 50, 54, 58, 60, 61, 62, 66, 68, 69, 70, 71, 73, 77, 80, 81, 85, 85, 86, 88, 89, 93, 94, 95, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 110, 111, 112, 114, 115, 116, 117, 118, 122, 123, 125, 128, 169, 209, 300, 301, 303, 304, 305, 306, 307, 308, 309, 310, 311, 312, 313, 403, 447, 448, 493, 509, 510, 542, 548, 549, 597, 637, 684, 689, 694, 711, 712, 767, 785, 786, 835, 950, 1005, 1021, 1022, 1025, 1040, 1041 (described in Kuneš *et al.*, 2009); 1014 (Dudová *et al.*, 2010); 1052 (Žák *et al.*, 2010); 1053 (Břízová, 2009); 1066 (Stebich & Litt, 1997); 1068, 1071, 1072 (Hahne, 1992) and 1074 (Skrzypek *et al.*, 2009).

Snail sites (id from Horáčková *et al.*, 2014; [http://ecology.cts.cuni.cz/?page\\_id=115](http://ecology.cts.cuni.cz/?page_id=115)): 8, 9, 16, 21, 22, 23, 31, 38, 40, 45, 46, 47, 48, 55, 64, 66, 70, 73, 78, 79, 84, 92, 93, 96, 114, 119, 128, 133, 138, 139, 140, 143, 146, 160, 164, 165, 166, 169, 170, 171, 174, 175, 177, 181, 188, 197, 198, 201, 202, 203, 205, 208, 210, 211, 213, 215, 217, 219, 220, 228, 231, 237, 244, 245, 247, 249, 251, 256, 263, 264, 265, 270, 271, 273, 277, 282, 286, 290, 291, 292, 294, 298, 300, 304, 311, 312, 314.

**Temperature:** We combined information on the Holocene temperature from two independent sources (Fig. 4). We used the mean values of data on oxygen isotopes from Greenland ice (Alley *et al.*, 1995) and temperature data from boreholes (Huang *et al.*, 2008) across the focal 200 year intervals (0-200 calBP, 200-400 calBP, ..., 14,400-14,600 calBP). In the analyses we discuss both types of proxy temperatures separately and indicate which of them is analysed. This is because each proxy temperature captures different aspects of the Holocene temperature variation.

**Reference point:** The values to standartize datasets (i.e., the values that define the Reference Point; see also Fig. 1) were set as  $d = 1\text{km}$ ;  $\Delta a = 0$ ;  $a_{min} = 300\text{m}$ ;  $\sigma_{min} = 1,000$  specimens and  $1\text{km}^2$  in plants and snails, respectively (see S6);  $\Delta\sigma = 0$ ;  $t_{acc} = 1\text{year}$ ;  $\Delta t_{acc} = 0$ ;  $N = 50^\circ$  and  $E = 15^\circ$ .

## S2: The Similarity Indices

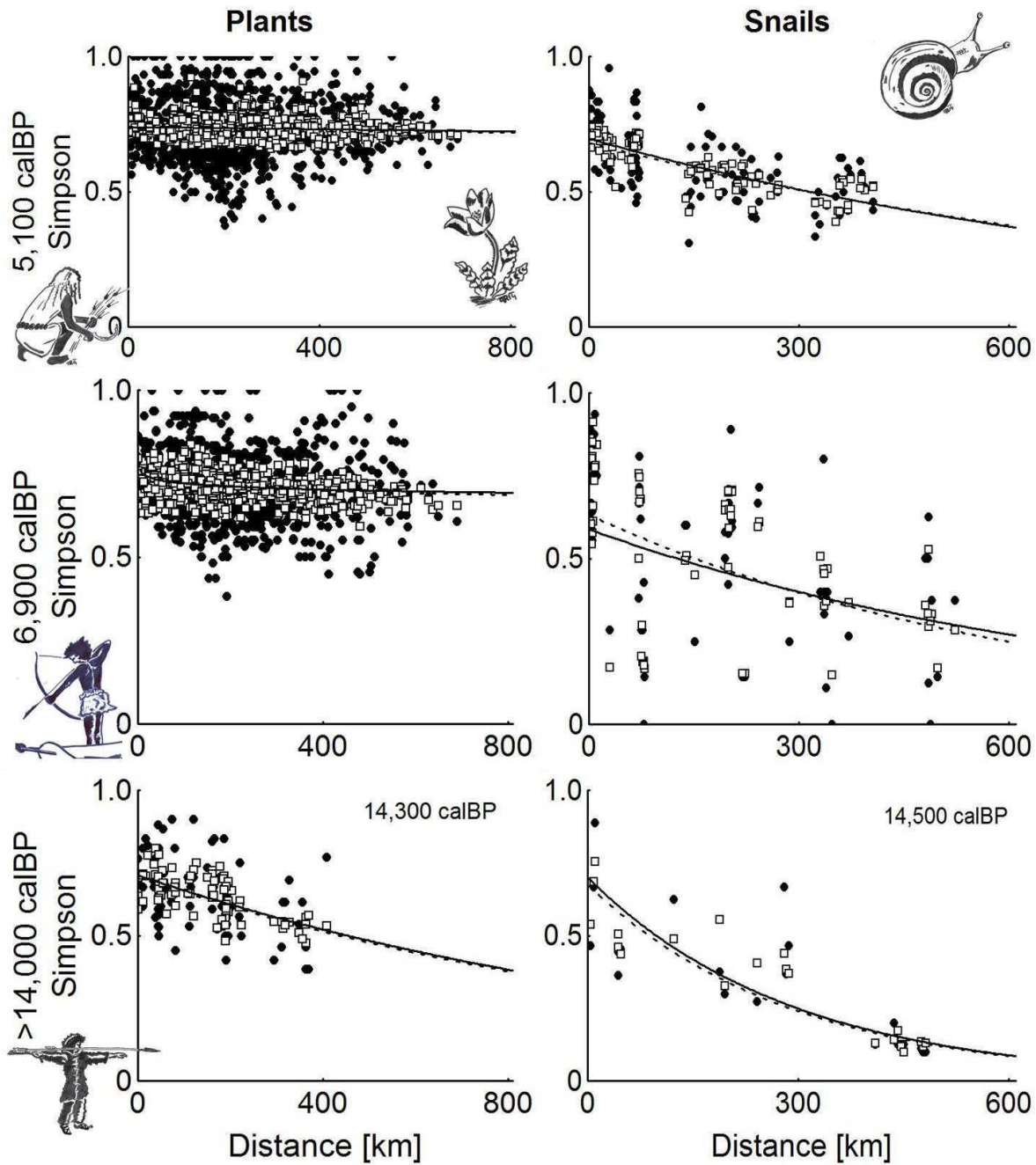


**Fig. S2:** This figure shows (A) how  $J$  (the Jaccard index) and  $\beta'_{Sim}$  (the one minus Simpson beta) are mutually related at their extreme values (0 and 1), and (B) the relationship between  $J$  and  $\beta'_{Sim}$ . By definition,  $J = S_{A \cap B} / S_{A \cup B}$  and  $\beta_{Sim} = (\min(S_A, S_B) - S_{A \cap B}) / \min(S_A, S_B)$  where  $S_A$  and  $S_B$  are species richness of the assemblages at sites A and B, and  $S_{A \cap B}$  is the number of species shared between assemblages at A and B,  $S_{A \cup B}$  is the species richness of the two sites combined. Apparently,  $\beta_{Sim}$  can be simplified to  $1 - S_{A \cap B} / \min(S_A, S_B)$ , so here we simply compute  $\beta'_{Sim}$  as  $S_{A \cap B} / \min(S_A, S_B)$ . The advantage of the  $\beta'_{Sim}$  over  $\beta_{Sim}$  is that it, similarly to  $J$ , measures similarity of two assemblages in terms of species composition.

(A) Four arrangements representing the extremes for species lists show that in three cases of four the  $J$  and  $\beta'_{Sim}$  equal each other. In the fourth case the  $\beta'_{Sim}$  reaches its maximum and  $J$  depends on the  $S$  of site B. Hence  $J$  can be read as a measure of species overlap, while  $\beta'_{Sim}$  is a measure of nestedness of the species lists. It follows that  $J$  is sensitive to the species overlap and  $S$  of both the sites together, while  $\beta'_{Sim}$  is sensitive to number of species that are unique to and  $S$  of the smaller assemblage.

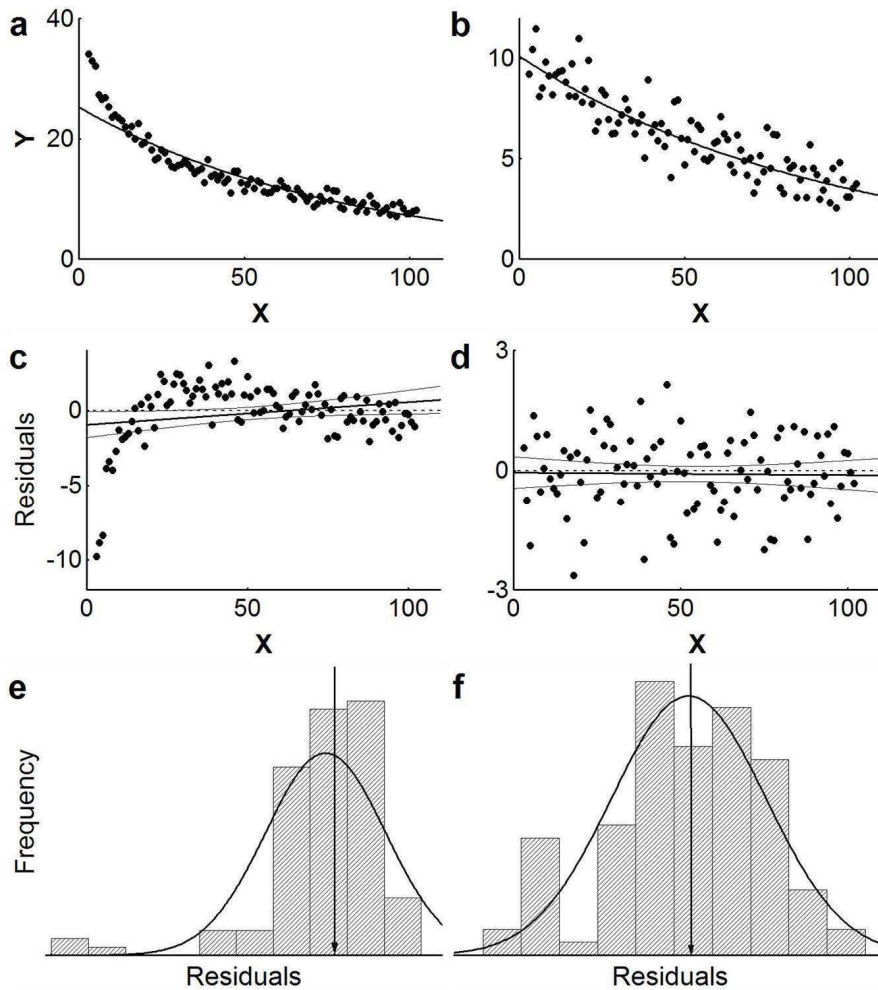
(B) The space of possible combinations between  $J$  and  $\beta'_{Sim}$  as modeled using 3,000 random simulations ( $a = \text{random}^{2.3}(0,1)$ ;  $b = \text{random}^{2.3}(0,1)$ ;  $c = \text{random}^{2.3}(0,1)$ ;  $J = a / (a + b + c)$ ;  $\beta'_{Sim} = a / \min(a + b, a + c)$ ).

### S3: $\beta'_{Sim}$ Decays



**Fig. S3:** Distance decays of  $\beta'_{Sim}$  for plants (1<sup>st</sup> column) and snails (2<sup>nd</sup> column) as observed (full symbols) and modeled (open symbols; Eq. 2 in Methods 2). Solid and dashed lines show exponential regression lines (regression lines for the model and data mostly overlap). Negative rates suggest a decreasing relationship, rates close to zero suggest small or no decay).

## S4: Fitting



**Fig. S4:** Exponential function (solid line) fitted on data that were generated using the hyperbolic function (A) and the exponential function (B) with normal error  $N(0,1)$ . Residuals between the data and model (C for hyperbolic decay, D for exponential decay). Solid lines show regression line and 95% confidence interval and dashed lines show zero level. The bottom row shows the frequency distributions of the residuals (E – hyperbolic decay, F - exponential decay). The arrow indicates the zero level. A,C and E show a biased fit that would negatively affect our results if it occurred.

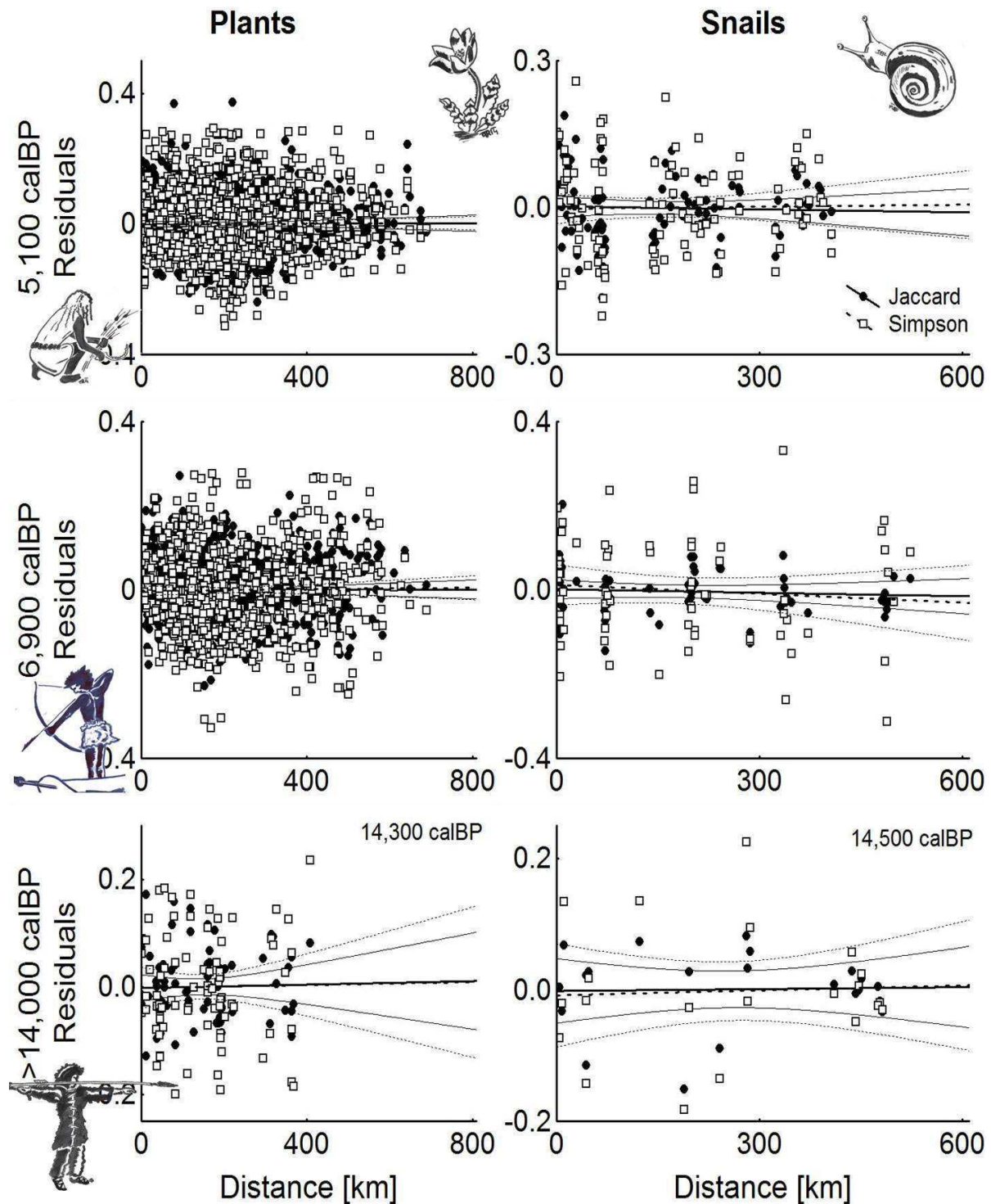
**Fitting:** Equations 1-3 were fitted in three steps: firstly standard fitting, i.e., multi-linear regression of log-transformed data, was applied. Secondly, rates of decay ( $r$ ) were held constant and initial indices ( $S_0, J_0, \beta_{Sim,0}$  here generally labeled  $I_0$ ) were fitted again ( $I_0 = \sum_i I_i e^{\sum_j r_j x_{ij}} / \sum_i e^{2 \sum_j r_j x_{ij}}$ , where  $x$  stands for a variable) to correct problems with asymmetric distribution of residuals and existence of zero indices. (Xiao *et al.*, 2011) Thirdly, to confirm the quality of exponential fitting (Xiao *et al.*, 2011) each parameter was randomly varied 3,000 times around its already estimated value and the set of parameters that better met the least square criterion were selected. This procedure was then repeated (starting in the best solution already found) until no better parameters were obtained.

**Bias:** The deviations of the fitted lines (solid, in C,D) from the zero level (dashed, in C,D) show bias, which is significant for hyperbolic data that are wrongly fitted using the exponential model. The mean value of the bias is also shown as the horizontal distance between the summit of the bell shaped curve (fitted Normal distribution) and zero (the arrow) in E and F. We checked our fitting for the significance and maximum value of the bias across the span of values of our predictors (for values see *S8.T1*). Our goal is insignificant bias that is considerably smaller than the variation of the indices across the Holocene.

**Error:** Error is shown as vertical distances between data points (filled circles) and model (solid line) in A,B and as vertical distances between data points (filled circles) and zero level in C,D. Our goal is symmetrically distributed errors with respect of the zero level. The symmetry of the errors was checked visually (for examples see Figs. 2,S3,S5,S7). The histogram and fitted normal distribution in E,F show frequency distribution of errors.

**Confidence intervals:** We utilized frequency distributions of errors (E,F) to compute 99% confidence intervals (see Figs. 3,5). Each confidence interval was constructed as the estimated focal index or  $S$  at the Reference Point (taken from Eqs. 1-3 in Methods 2) plus/minus the confidence value. The confidence values are equal to the standard deviation of the residuals multiplied by  $t$ -statistics for 0.01 level and  $N - 1$  degrees of freedom. Our confidence intervals therefore account for the variation in sample size. The smaller  $N$  the wider confidence interval.

## S5: Residuals in Similarity Indices



**Fig. S5:** Residuals between observed and modeled  $J$  (solid symbols) and  $\beta'_{Sim}$  (empty symbols) for plants (1<sup>st</sup> column) and snails (2<sup>nd</sup> column). Solid and dashed lines show linear regression lines (regression lines for  $J$  and  $\beta'_{Sim}$  mostly overlap the axis of zero) and 95% confidences across the plot, respectively.

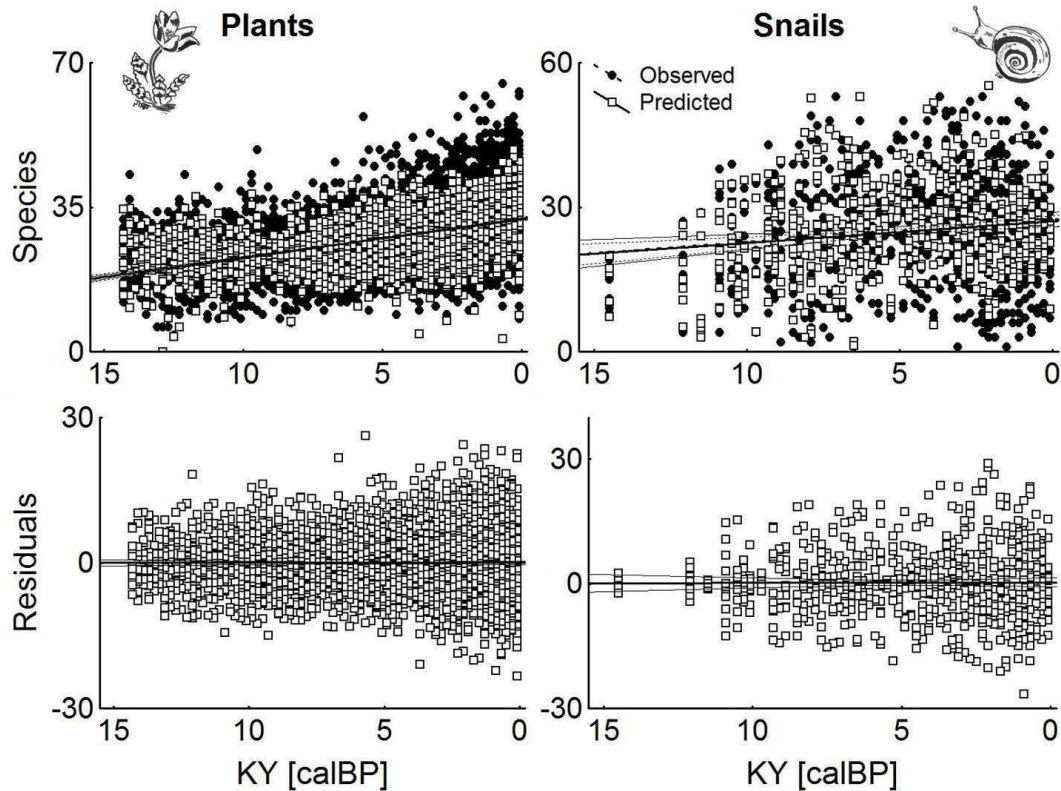


## S6: Data Standardization and Sampling Effort

The equations 1-3 allow to standardized our data by (i) fitting them on each dataset for particular time level (e.g., 100 calBP, 300 calBP ...) separately and then, having the fitted parameters (ii) computing  $S$ ,  $J$  and  $\beta'_{Sim}$  for standard (the same for each time level) values, which comprise high sampling effort, the same period of sample accumulation, equal sample location and between samples distance.

Both the snail and plant data were fitted by Eqs. 1-3. There was, however, one exception. Whilst for plants the sampling effort ( $\sigma$ ) was expressed as the number of counted specimens (pollen grains) in a sample, it was the area from which the snail shells were accumulated in the case of snail data. In snails, the  $\sigma$  stands therefore for the focal sampled area. These were typically slopes under which the sediments were collected.

## S7: Species Richness



**Fig. S7:** Observed (solid symbols) and modeled (empty symbols; Eq. 1 in Methods 2)  $S$  (1<sup>st</sup> row) and residuals between them (second row) vary in time for plants (1<sup>st</sup> column) and snails (2<sup>nd</sup> column). Solid and dashed lines show linear regression lines (regression lines for observed and modeled species richness mostly overlap each other) and 95% confidences across the plot, respectively.

## S8: Tests

*T1, bias* - No significant relationship between residuals and the focal predictors has been detected (GLM, linear link), except in the case of plant's Jaccard index, which was significantly biased by altitude ( $p \cong 3 \cdot 10^{-4}$ ,  $N = 86$ ). Mean values of residuals did not significantly differ from zero values (i.e.,  $CI_{0.01}$  of mean values overlapped zero). The extreme values of the bias ( $S4$ ) across the span of the predictors are (i)  $-5 \cdot 10^{-4}$  and  $4 \cdot 10^{-4}$  for plant Jaccard index, (ii)  $-4 \cdot 10^{-3}$  and  $2 \cdot 10^{-2}$  for snail Jaccard index, (iii)  $-3 \cdot 10^{-4}$  and  $4 \cdot 10^{-3}$  for plant Simpson beta, (iv)  $-7 \cdot 10^{-3}$  and  $3 \cdot 10^{-2}$  for snail Simpson beta and (v) less than 0.4 and 3 for plant and snail species richness across all analyses). The lack of significant bias and its negligible values ensure that the detected trends (i.e., increase, decrease, constant) of the indices, their distance rates and local  $S$  are correct even though any particular predicted value can be challenged. In other words, we did not eliminated the error, but we eliminated a bias.

*T2, prior to analyses (normality, artefactual predictors and significance level)* – Prior to the analysis, normal probability plots of all variables were visually inspected. Only frequency distributions of temperature proxies and  $N$  were too negatively skewed to run the test properly, and snails' distance rates had higher kurtosis than the normal distribution. We therefore transformed the variables using  $h(x) = -10\log(1 - (x + 44)/4900)$  and  $h(x) = \log(x)$  for plants' and snails'  $N$ , respectively;  $h(x) = 10^4x + 10$  and  $h(x) = 10^5x + 70$  for plants' rates of distance decays in  $J$  and  $\beta'_{Sim}$ , respectively;  $h(x) = \log(40 - 1,000(\text{sgn}(x - \bar{x})\text{abs}^{0.5}(x - \bar{x}) + \bar{x}))$  and  $h(x) = 1,000(\text{sgn}(x - \bar{x})\text{abs}^{0.6}(x - \bar{x}) + \bar{x}) + 31$  for snails' rates of distance decays in  $J$  and  $\beta'_{Sim}$ , respectively;  $h(x) = k^{-1}\log(k(x - \bar{x})/S_x + 1)$  ( $S_x$  stands for estimation of variance;  $k = -2.5$  in plants and  $-1.5$  in snails) for oxygen-isotope temperature proxy, and  $h(x) = -\log(10 - x)$  for borehole temperature data. Year values, mean altitude and total sum of checked pollen grains were standardized by dividing with 20,000, 1,000 and 130,000, respectively. Overdispersion was not visually detected, so we used Wald Z-statistics. Because we expected exponential decay, we used the log-link in our tests. Although the similarity indices are bounded by zero and one, their variance is so small that they were considered as if they obeyed the Normal distribution.

In the next step we checked for significance of the artefactual variables that may mistakenly affect our result. If such variables were identified, they would be involved into the GLM analyses (to filtrate them out), but they would not be discussed. We suspected that the artefactual effects might be (a) tree proportion (only in plants), (b) number of sites with preserved samples (not all the samples were preserved for all the 200 years lasted time window, Fig. 1), and (c) mean altitude (only in plant's  $J$ ). All mean values were considered across all points within the focal 200 years lasted time window (Fig. 1).

*a* - the high proportion of trees at a site would decrease the distance from which the pollen grains are transported to the sample, which may artefactually reduce the detected plant's  $S$  and consequently the detected plant similarity indices and their distance rates. The distance decay in  $J$ , which is  $S$  sensitive, would therefore be artefactually steeper. The high proportion of trees also decreases the number of pollen grains of the other plants in the sample, because trees are massive pollen producers. This effect would therefore artefactually lessen the sampling effort (which could not be corrected by Eqs. 1-3 in Methods 2) and it would also result in artefactually smaller  $S$  with all the above explained consequences.

*b* – the potential effect of the number of palaeontologically preserved sites could not be corrected using Eqs. 1-3 in Methods 2. It could, however, bias the indices and their distance rates by the same mechanism such as the sampling effort.

*c* – The effect of mean altitude on *J* is usually considered as a biologically founded effect (Jost, 2010; Tjørve & Tjørve, 2008). Although it has been corrected using the Eq. 2 in Methods 2, there was a significant bias of residuals between plant's *J* observed and predicted by Eq. 2 in Methods 2. Moreover, samples extracted from particular 200 year time windows varied in mean altitude, which may artefactually drive *J*, without the corresponding changes in ecological rules. Therefore we control for this effect in this step of our analysis, although it has already been filtered by the Eq. 2 in Methods 2. It applies only for plants' *J*.

Only *N* of sites in plants significantly increased the rate of plants' distance decay in  $\beta'_{Sim}$  ( $p < 4 \cdot 10^{-4}$ ,  $N = 72$ ), and the proportion of trees in pollen spectrum increased plant *J* ( $p < 4 \cdot 10^{-3}$ ,  $N = 72$ ) and rate of distance decay in  $\beta'_{Sim}$  ( $p < 4 \cdot 10^{-3}$ ,  $N = 72$ ). Because the proportion of trees only affected (i) *J* but not its rate, (ii) rate in  $\beta'_{Sim}$  but not the index itself, and (iii) did not affect the *S* which would be definitely affected if the proportion of trees acted as an artefactual independent parameter, we consider the proportion of trees as a biologically founded predictor.

We run five independent analyses (the analysis for *S*, *J*,  $\beta'_{Sim}$ , and their rates of distance decay) for plants and snails and for four nonoverlapping periods. Other analyses are not independent from these 40 tests. We thus apply Bonferroni correction to the significance level 0.05 and therefore we will use the level  $1.3 \cdot 10^{-3}$ . In some cases, however, when a theory and/or logic and consistency of our tests suggest that a predictor with *p* between  $1.3 \cdot 10^{-3}$  and 0.01 must affect our variables, we break the rule and state that the predictor is significant.

*T3, Temporal trends since 14,500 calBP* – We used linear link in the analysis, for the increase of *J* and  $\beta'_{Sim}$  apparently does not reach saturation close to the bottom or upper limits of the indices (i.e., 0 or 1). *J* and *S* significantly increases toward present (plants:  $p_J < 1 \cdot 10^{-6}$ ;  $p_S < 1 \cdot 10^{-6}$ ;  $N = 72$ ; snails:  $p_J < 5 \cdot 10^{-4}$ ;  $p_S < 4 \cdot 10^{-4}$ ;  $N = 54$ ). The rates of distance decays in *J* (snails only) and  $\beta_{Sim}$  (plants only) also significantly increase toward the present, but the significances are sensitive to the values before the year 12,200 calBP. We will therefore be careful when we discuss the trends in the rates.

*T4, Temporal trends within the periods* – Here we account for the artefactual variables and Bonferroni correction (GLM, linear link).

**12,200 - 9,600 calBP.** The plant's distance decays in similarity indices were growing flatter between 12,200 and 9,600 calBP ( $p < 7 \cdot 10^{-4}$  and  $p < 2 \cdot 10^{-6}$ , for *J* and  $\beta'_{Sim}$ ;  $N = 12$ ). Snail's *J* and *S* significantly increase toward the present within 14,600-1,600 calBP ( $p < 2 \cdot 10^{-4}$  and  $p < 8 \cdot 10^{-6}$ , respectively;  $N = 46$ ). This increase would be significant even at smaller scale (14,600-5,800 calBP) but only without the Bonferroni correction ( $p < 5 \cdot 10^{-3}$  and  $< 8 \cdot 10^{-3}$ ;  $N = 25$ ). The fact that we need longer periods to show a significant trend in snails can be explained by the noisy data.

**9,600 – 5,800 calBP.** The increase in the  $S$  for snails follows from the visual inspection of Fig. 3F and significance within the period 14,600-1,600 calBP (see above). The  $S$  in plants has been increasing since 9,600 calBP ( $p < 1 \cdot 10^{-6}$ ;  $N = 48$ ). Apart from  $S$ , plant's distance decay in  $J$  grew steeper between 9,600 and 5,800 calBP ( $p < 6 \cdot 10^{-4}$ ;  $N = 19$ ). For the test of the jump in  $J$  see the next period.

**5,800 – 1,600 calBP.** From 9,000 calBP the differences between  $J$ s of consecutive time windows (hereafter jumps in  $J$ ) oscillates around the mean level of  $-1.34 \cdot 10^{-3}$  with standard deviation  $3.153 \cdot 10^{-2}$  ( $N = 44$ ). The normal probability plots indicates that the jumps in  $J$  are normally distributed. The jump in the time window 5,800 calBP ( $\Delta J = 0.106382$ , Fig. 3A) therefore lies at the app. 99.94% two-tales quantile and the significance of the jump is app.  $6 \cdot 10^{-4}$ . The high significance of the jump at app. 5,800 calBP is also shown in Normal probability plot, where the point for this time window is shown as an outlier (S12).

**1,600 calBP – to the present.** We detected significant ( $p < 4 \cdot 10^{-4}$ ,  $N = 8$ ) increase of plant's  $J$  after 1,600 calBP.

*T5, drivers* – GLM (log-link, normal distribution) was applied to both the similarity indices, their distance rates and  $S$ . Predictors were (i) year (that is a proxy for successional sequence), (ii) both the proxy temperatures (borehole, and oxygen isotope), (iii)  $S$  (only in  $\beta'_{Sim}$  and their rates of distance decay), (iv) mean proportion of tree pollen grains in sample (in plants only), and (v) the artefactual parameters as identified in *T2*. A stepwise procedure based on expert knowledge (Flom, 2009), where each step was individually judged by us, was performed. This means that various combinations of predictors were analysed in order to avoid the unintended effects. The worse significance across the reasonable combinations of predictors analysed was then considered. The term 'reasonable combinations' means that (i) the results that were obtained using a combination of the linearly scaling predictors were taken only as an additional information that helped to resolve the equivocal results and that (ii) we considered the possible mechanisms that were already published (effects of  $S$  and trees proportion) or here assumed (effect of temperature, successional sequence and/or agricultural activity). Before 5,800 calBP a linear scaling was visually detected between the year, tree proportion and borehole temperature proxy in plants, and between year and borehole temperature proxy in snails. After 5,800 calBP a linear scaling was detected between  $S$ , year and proportion of tree pollen grains in plants, and between year and the borehole proxy temperature in snails.

### **plants after 5,800 calBP**

$J$  – Only year, borehole temperature proxy, and  $S$  cannot be deleted from the list of predictors based on their statistical significance ( $p_t \cong 2 \cdot 10^{-5}$ ;  $p_y \cong 3 \cdot 10^{-6}$ ;  $p_S \cong -1.1 \cdot 10^{-5}$ ;  $N = 29$ ; positive and negative values stand hereafter for increasing and decreasing relationships, respectively; hence, the increase in the  $J$  toward the past and decreases toward the present is suggested by the positive value of  $p_y$ ). If two or all three of these predictors were analysed together they become insignificant. We consider temperature as an unlikely predictor, because the effect of oxygen isotope proxy temperature is statistically insignificant. To maintain consistency with literature (Koleff & Gaston, 2002; Jost, 2010), we should prefer  $S$  as the likely predictor. However, the statistics signalizes no effect of  $S$  nor year before 5,800 calBP - in which case a correlation between  $S$  and year is weaker than in the later period.

We therefore conclude that  $S$  is the likely predictor, although, we cannot exclude that it is the successional sequence or temperature.

**rate of distance decay in  $J$**  – no predictor was found significant.

$\beta'_{Sim}$  – no predictor was found significant.

**rate of distance decay in  $\beta'_{Sim}$**  – no predictor was found significant.

$S$  – The oxygen isotope ( $p_t \cong -1.7 \cdot 10^{-3}$ ;  $N = 29$ ) and borehole ( $p_t \cong -9 \cdot 10^{-6}$ ;  $N = 29$ ) proxy temperatures, as well as year ( $p_y \cong -2 \cdot 10^{-4}$ ;  $N = 29$ ) were significant on their own. When year and temperature proxies are combined in the analysis, the effect of year becomes even more significant ( $p_y \cong -1 \cdot 10^{-6}$ ;  $N = 29$ ). A combination of proxy temperatures does not affect their significance, the reason might be that the proxy temperatures do not scale with each other considerably in this period, each capturing temperature in slightly different area. Most importantly, however, the temperature proxy scales with  $S$  in different direction than supposed by the metabolic theory. The successional sequence (i.e. year) is thus supposed to drive plant  $S$  after 5,800 calBP, although the role of temperature cannot be rejected based on our statistics.

### **plants before 5,800 calBP**

$J$  – only the effect of tree proportion could not be rejected ( $p_{tree} \cong 1 \cdot 10^{-4}$ ;  $N = 43$ ). Both temperature proxies are nearly significant ( $p_t < 3.5 \cdot 10^{-3}$ ;  $N = 43$ ). The temperature proxies are, however, significant when we control for sampling effort ( $p_t < 1 \cdot 10^{-3}$ ;  $N = 43$ ) and the oxygen isotope proxy is even more significant in this case ( $p_t \cong 6 \cdot 10^{-5}$ ;  $N = 43$ ). The effect of  $S$  is insignificant, and any combination of  $S$  and other variable in the analysis decreases significance of the analysed variables.

**rate of distance decay in  $J$**  – both proxy temperatures, year, and tree cover have significant effect only without one another ( $p_t < 6 \cdot 10^{-6}$ ;  $p_y \cong -1 \cdot 10^{-5}$ ;  $p_{tree} \cong 2 \cdot 10^{-4}$ ;  $N = 43$ ). Any combination of the focal variables decreases the significance.

$\beta'_{Sim}$  – no predictor was found significant.

**rate of distance decay in  $\beta'_{Sim}$**  – no predictor was found significant.

$S$  – The oxygen isotope ( $p_t \cong 1.3 \cdot 10^{-3}$ ;  $N = 43$ ) and borehole ( $p_t \cong 5 \cdot 10^{-5}$ ;  $N = 43$ ) proxy temperatures, as well as year ( $p_y \cong -2 \cdot 10^{-4}$ ;  $N = 43$ ) were significant on their own. Any combination of focal variables, however, decreases the significance. Moreover,  $S$  scales with temperature in opposite manner than in the period after 5,800 calBP, and visually,  $S$  stagnates when temperature increases and increases when temperature stagnates. Hence the successional sequence is suspected to drive  $S$  in plants, although the role of temperature cannot be rejected based on our statistics.

### ***snails after 5,800 calBP***

***J*** – Species richness ( $p_S \cong 2 \cdot 10^{-3}$ ;  $N = 25$ ) was identified as a significant predictor of *J*. Although the presence of the temperature proxies increases the significance of *S*, temperature is not significant in neither combination of the predictors.

**rate of distance decay in *J*** – no predictor was found significant. Only the borehole proxy temperature was found nearly significant ( $5 \cdot 10^{-3} < p_t < 6 \cdot 10^{-3}$ ) in some combinations of the predictors examined.

$\beta'_{Sim}$  – no predictor was found significant.

**rate of distance decay in  $\beta'_{Sim}$**  – no predictor was found significant.

***S*** – no predictor was found significant.

### ***snails before 5,800 calBP***

***J*** – only *S* was found significant ( $p_S \cong 1 \cdot 10^{-6}$ ;  $N = 25$ ) and presence of the other predictors decreased its significance.

**rate of distance decay in *J*** – We identified year ( $p_y \cong 5 \cdot 10^{-3}$ ;  $N = 25$ ) and temperature ( $p_t \cong 5 \cdot 10^{-3}$ ;  $N = 25$ ) as the drivers of distance rate in *J*; although they are insignificant after the Bonferroni correction. Neither of them were significant on their own and the oxygen isotope proxy temperature was never significant even in combination with the other drivers. However, the presence of oxygen isotope proxy temperature in analyses increases the significance of the year from app.  $2 \cdot 10^{-2}$  to app.  $5 \cdot 10^{-3}$ , and the presence of the borehole proxy temperature increases the significance of year from 0.9 to app.  $5 \cdot 10^{-3}$ . On the other hand, the presence of the year in the analysis increases the significance of the borehole proxy temperature from app. 0.7 to app.  $5 \cdot 10^{-3}$ , and the significance of oxygen isotope proxy temperature from app. 0.3 to app.  $9 \cdot 10^{-2}$ . The successional sequence and temperature thus act together.

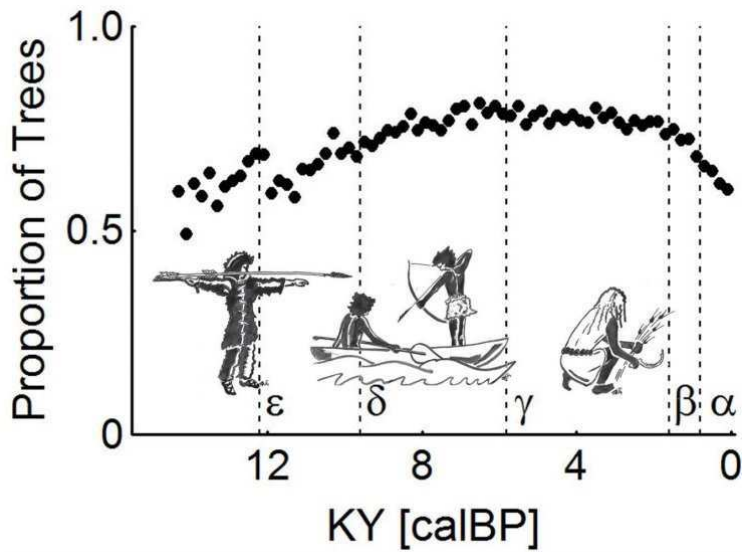
$\beta'_{Sim}$  – no predictor was found significant.

**rate of distance decay in  $\beta'_{Sim}$**  – no predictor was found significant.

***S*** – Year ( $p \cong -4 \cdot 10^{-3}$ ;  $N = 25$ ) and temperature ( $p \cong 5 \cdot 10^{-4}$ ;  $N = 25$ ) are clearly significant. Both the proxy temperatures and year increase the significance (i.e. decrease *p*) of each other, therefore they act together.

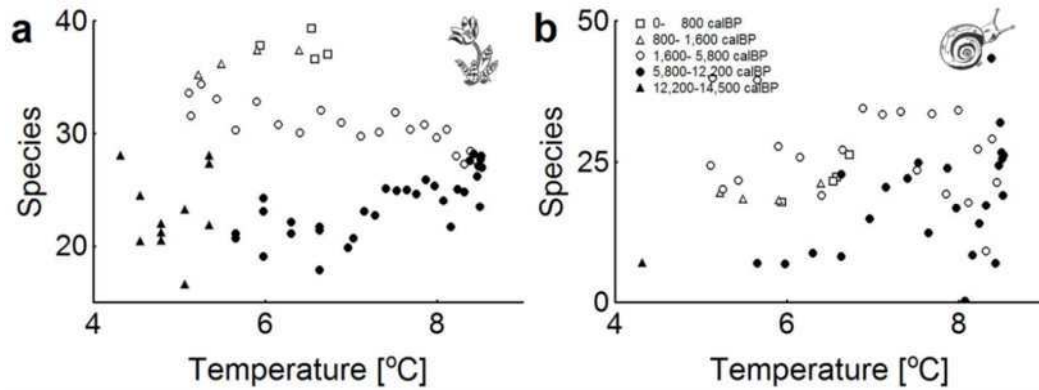
***T6, relationships*** - The 99.9% intervals of the intercepts of the relationships between *J* and *S* are [0.12,0.51] and [0.52,0.86] for the years before and after 5,800 calBP, respectively. The intervals miss each other, the relationships before and after 5,800 calBP therefore deviates from each other with significance ( $p < 1 \cdot 10^{-3}$ ).

### S9: Tree Cover



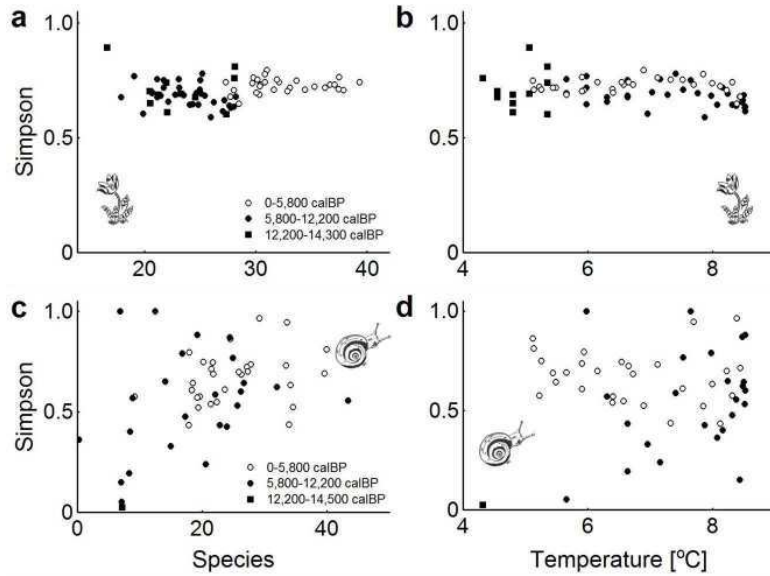
**Fig. S9:** Variation of the mean proportion of tree pollen grains in samples. The lack of a jump at about 5,800 calBP ( $\gamma$ ) suggests that the event 5,800 calBP is not artefactually caused by change in tree cover.

### S10: Species Richness – Temperature Plots



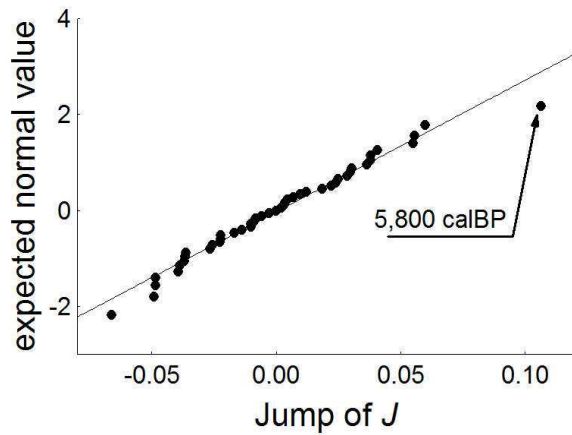
**Fig. S10:** Relationship between  $S$  and temperature (Huang *et al.*, 2008) in plants (A) and snails (B).

### S11: $\beta'_{Sim} - S$ – Temperature Relationships



**Fig. S11:** Response of plant (A,B) and snail (C,D) assemblages, as measured by  $\beta'_{Sim}$ , to variation in  $S$  (A,C) and temperature (Huang *et al.*, 2008) (B,D). Full symbols label the periods before the year 5,800 calBP, empty symbols label the periods after the year 5,800 calBP.

### S12: Jumps of Jaccard Index



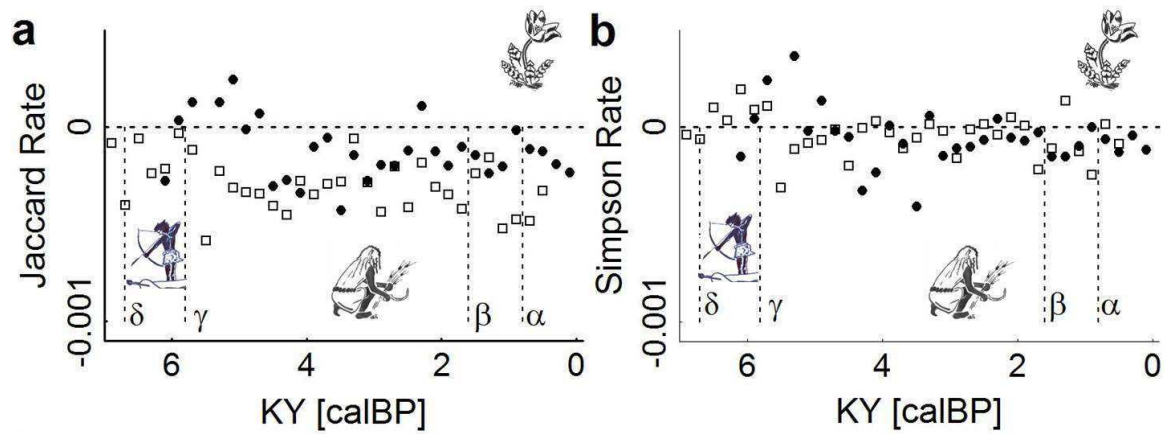
**Fig. S12:** The jump of  $J$  at app. 5,800 calBP that is apparent in Fig. 3A is also an apparent outlier in the normal probability plot. Jump in  $J$  is here the term for the differences between  $J$ s of two consecutive 200 years windows.



### S13: Scenario

The scenario of the change at about 5,800 calBP may follow as: long-term climatically driven processes successively exhausted the soils which allowed the *Fagus* and *Abies* to extend their ranges. The same event may simultaneously have triggered a change in agricultural management. As soil became exhausted, fields had to be extended and pastures moved further into the wild, which only magnified the already running process. This hypothesis is supported by increasing presence of plants that indicate pastures and acidic, nutrient-poor soils (*Calluna vulgaris*, *Plantago lanceolata*, *Plantago major/media*, *Rumex acetosa*-type and *Melampyrum pollen*), sudden occurrence of steppe snail immigrants (*Cepaea vindobonensis*, *Oxychilus inopinatus*) and decreasing diversity of canopy forest snail species.

### S14: Rates of Distance Decay



**Fig. S14:** Difference between the rates of distance decay of the wild plants (empty squares) and agricultural (full circles) landscape.