PSEUDOPROXY MODELLING TO ASSESS UNCERTAINTIES IN PALAEOECOLOGY

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Introduction

- Palaeoecology plays a crucial role in understanding how ecosystems have responded to changing environmental conditions in the past.
- However, palaeoecological data are subject to sources of uncertainty that affect inferences drawn from them.
- Here, we show a virtual ecological[1] approach to assessing uncertainty by systematically introducing uncertainties to simulated data, then assessing the results of statistical analyses.

Methods

- Pseudoproxy[2] abundances are simulated as a function of environmental drivers following a proxy system modelling[3] framework.
- Pseudoproxies are subjected to simulated degradation and observational processes (mixing, sub-sampling, and proxy counting).
- Initial pseudoproxies act as 'error-free' abundances. Degraded and sampled pseudoproxies represent what we observe. Both the 'error-free' and observed data are analysed as empirical data.

Simulation

Pseudoproxy archives are generated as a function of interacting drivers (fig 1), allowing for different environmental conditions to be tested. Pseudoproxies mimic the statistical properties of empirical data without the same constraints.

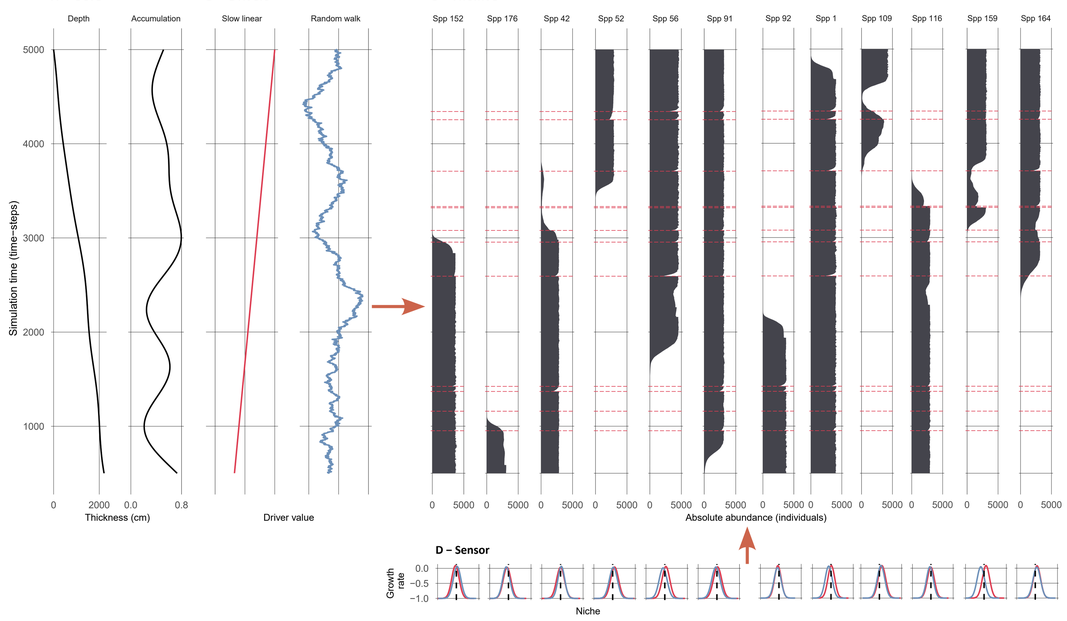


Figure 1: Representation of each component of the simulation: the accumulation rate and length of the core (A), driver conditions over time (B), abundances of pseudoproxies in the archive (C), and the niche of each species with respect to the driving environment (D). The linearly increasing driver (red) causes a gradual species turnover while the random walk (blue) indroduces variability in population abundances.

Degradation

(mixing)

The pseudoproxy archive has an accumulation rate, length, and time-span to represent a core-type sample. After degradation and observation of the benchmark data, the result is comparable to empirical data (fig 2).

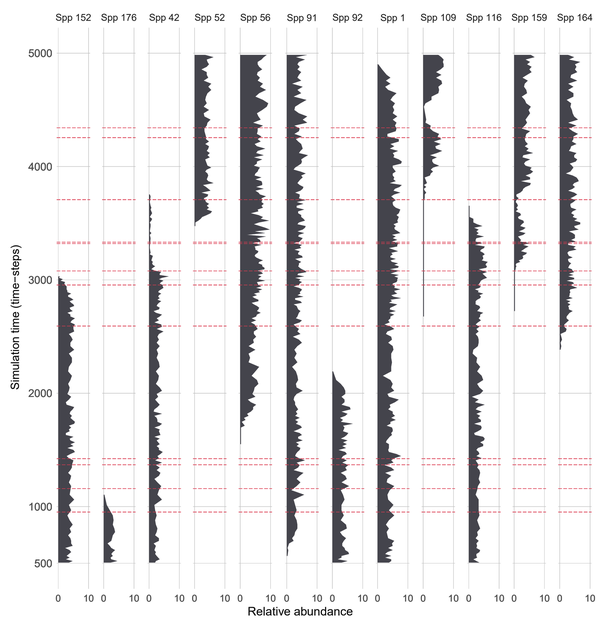


Figure 2: The observed pseudoproxy record after mixing, sub-sampling and proxy counting. The same subset of spcies from fig 1 are shown here. Note, the y axis is simulation time which runs from past to present. Time-step 5000 is the most recent part of the core.

Observation

(sub-sampling/counting)

Across replicate simulations, the difference in the analyses of the 'error-free' benchmark and increasingly uncertain data is quantified using feature analysis on the Fisher Information series. The example (fig 4) shows the change in Euclidean distance for combinations of two uncertainties.

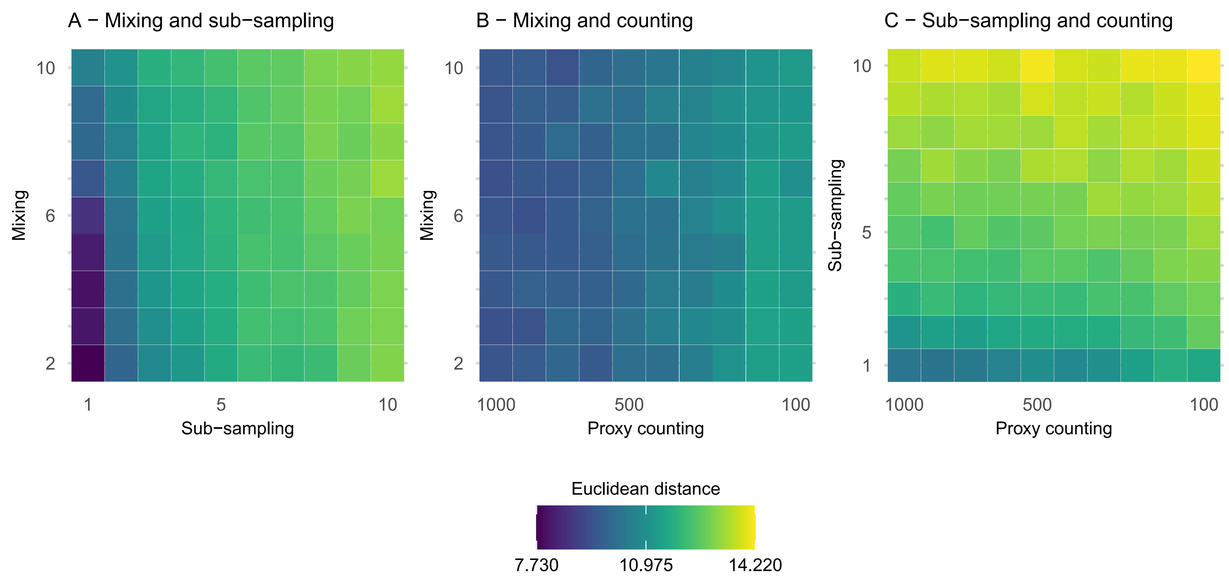


Figure 4: Shows how combined uncertainties: mixing with sub-sampling (A); mixing with proxy counting (B); and sub-sampling with proxy counting (C), influence analyses of pseudoproxy records. This analysis is done across replicate runs for every level of uncertainty, individually and combined. Here we show two uncertainties combined, the interaction effect of combined uncertainties is visible on the diagonal of each plot from bottom left to top right.

Analysis

Both the 'error-free' and observed data are analysed in the same way to determine whether features of the 'error-free' dataset are detectable in the observed data. Fisher information is used as one example (fig 3).

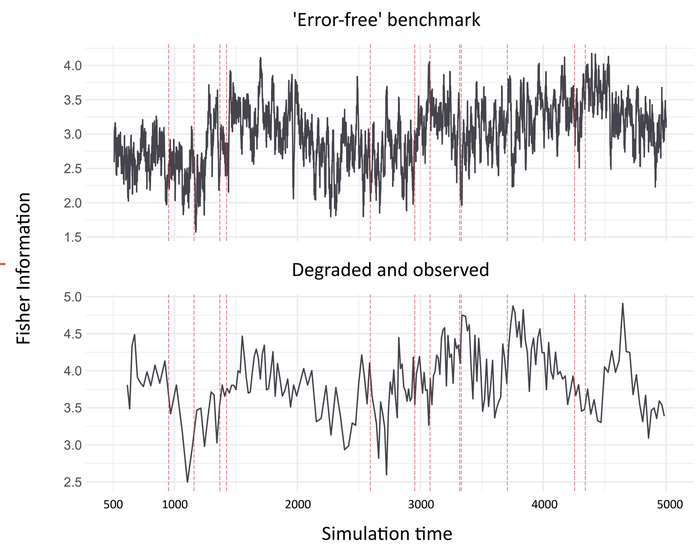
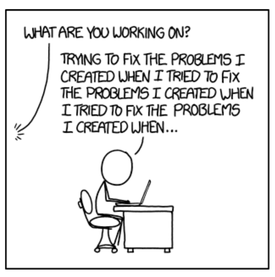


Figure 3: Example of one analysis (Fisher information) applied to both the undegraded, and the degraded/observed data. In this replicate some patterns are reversed in the degraded record (between 3500-4500 time-steps) and the gradual turnover is harder to see.

Evaluation



Conclusions

The virtual approach helps inform: (i) the influence of uncertainty on data and statistical inferences drawn from them, (ii) the appropriate selection and application of statistical methods for a given dataset with regards to uncertainty. (iii) Where to focus effort in the field and lab (e.g., spatial replication vs sub-sampling resolution) for a given research question.

Simulation allows us to generate many thousands of replicate cores but cannot entirely substitute for reality. Ultimately, we want to bridge the gap between simulation and empirical work (image left, both are me).

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Reference:
1. Zurell, D. et al. (2010) 'The Virtual Ecologist Approach: Simulating Data and Observers'
2. Mann, M.E. and Rutherford, S. (2002) 'Climate Reconstruction Using `Pseudoproxies''
3. Evans, M.N. et al. (2013) 'Applications of Proxy System Modeling in High Resolution Paleoclimatology'

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