Signal or noise? Testing hypotheses about faunal turnover

THE GEORGE WASHINGTON UNIVERSITY
WASHINGTON, DC

W. Andrew Barr

CASHP

Problem

Patterns of faunal turnover have been interpreted as reflecting the impact of external stimuli such as climate change on mammalian evolution (*e.g.*, Bobe *et al.*, 2002, Bobe & Behrensmeyer, 2004). Specifically, the origin of genus *Homo* has been linked to a pulse of turnover events caused by global climate change (Vrba, 1988, 1995).

However, stochastic speciation and extinction processes can also produce pulses of turnover events in the absence of external forcing. There is no agreed upon method for distinguishing signal from noise.

I use birth-death simulations with constant speciation probabilities to explore the factors influencing the detection of turnover pulses. Results can be used to calibrate hypothesis tests based on the fossil record in order to avoid false positives.

Methods

Simulations: 200 fossil records were simulated (Figure 1A), using the paleotree R package (Bapst, 2012; R Core, 2015). Simulation parameters were drawn from uniform distributions with the ranges shown in Table 1. **Detecting pulses**: Fossil records were divided into time bins (Fig. 1B). Turnover rates for bins were computed using Foote's (2000) per-capita rates of origination. Rates were compared to other bins, excluding the first and last. A turnover pulse criterion (*e.g.*, 1.5 times the interquartile range of origination rates) was applied (Fig. 1C), and any pulses noted (Fig. 1D).

Test of Simulation Parameters: Pulses were detected in each fossil record using time bins of 0.5 Ma and a pulse criterion of 1.5 * IQR. ANOVA was used to test for a relationship between simulation parameter values and the number of pulses detected. **Test of Analytical Parameters**: Pulses were detected in each fossil record with time bins of 0.5 Ma and a pulse criterion of 1.5. The proportion of fossil records showing at least one pulse was noted. Analytical parameters were incremented over the range in Table 1. At each increment, the pulse detection procedure was re-applied using the incremented analytical parameter. Loess regression was used to visualize the relationship between parameter values and the proportion of records showing a pulse.

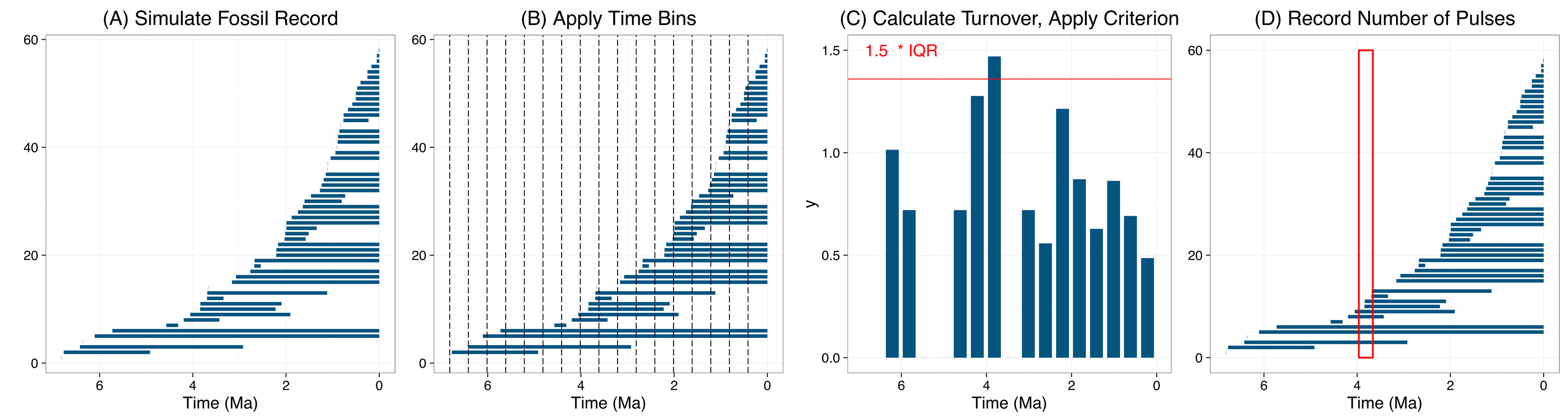

Figure 1 A-D: Schematic illustration of methods.

Simulation Parameter	Range
Origination Rate	0.3 - 0.6
Extinction Rate	0.1 - 0.3
Total Simulated Time	4 - 8 Ma
Total Taxa Sampled	30 - 100
Initial Diversity	1 - 5
Taxon Sampling Rate	0.5 - 2
Analytical Parameter	**Range**
Length of Time Bins	0.2 - 1.6 Ma
Turnover Pulse Criterion	1.5 - 3 (IQR)

Table 1: Simulation and analytical parameters used in this study.

Results

Simulation Parameters

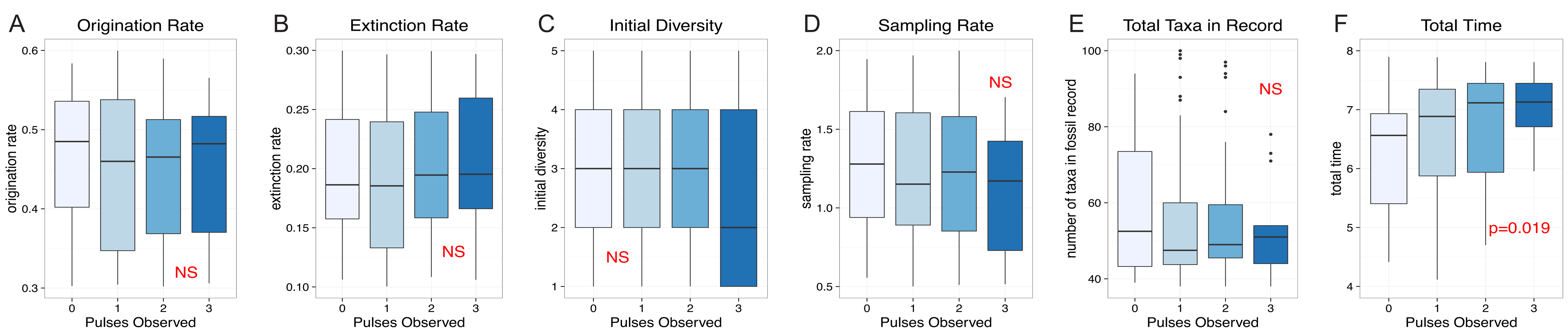

Figure 2 A - F: Boxplots showing relationship between simulation parameters and number of pulses detected. Significance test are from ANOVA.

Analytical Parameters

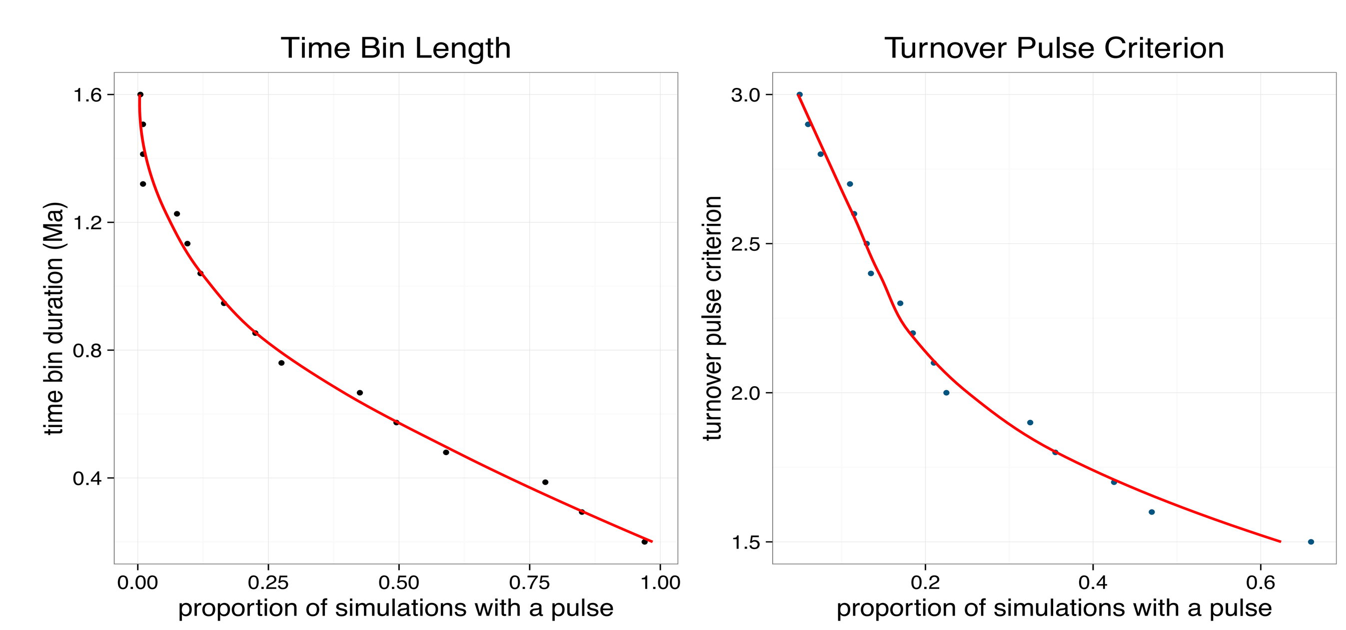

Figure 3 A and B: Regressions showing relationship between analytical parameters, and proportion of records showing a turnover pulse.

Discussion

Most of the simulation parameters do not significantly predict the number of turnover pulses detected (Fig 2). The only significant predictor of the number of pulses was the total time of the simulation (Fig 2F). Other things being equal, longer simulations tend to have more turnover pulses. This is likely because longer simulations reduce the average number of taxa per bin, which results in a noisier dataset. While the total number of taxa is not a significant predictor of the number of pulses, high numbers of taxa are rarely associated with high numbers of pulses.

Extinction and origination rates do not have a consistent impact on number of pulses observed. This is likely because the simulations are constrained in the number of taxa allowed. If the number of taxa were unconstrained, higher origination rates and lower extinction rates would increase the total number of taxa, and the number of taxa per time interval. This would likely reduce the number of pulses.

The analytical parameters (bin length and the pulse criterion) have very clear relationships to the number of pulses detected (Fig 3). More stringent criteria and longer time bins rapidly reduce the probability of detecting a pulse.

Conclusions

Analytical parameters have a profound impact on probability of detecting turnover pulses. Time bin length and turnover pulse criterion must be chosen carefully to ensure reasonable Type I error rates.

There are potentially high Type I error rates in simulations with parameters similar to estimates from the African bovid fossil record. This underscores the recent conclusion of Bibi & Kiessling (2015) that bovid turnover is best viewed as relatively continuous.

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Affiliation

Center for the Advanced Study of Human Paleobiology.
Department of Anthropology. The George Washington University.
Washington DC