

How do species traits affect extinction risk?

New approaches to old questions.

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The Paleobiology Database
revealing the history of life

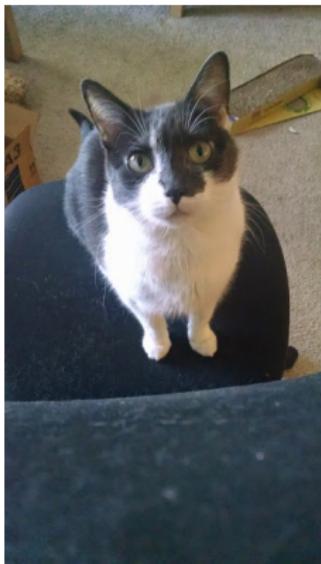


Question

Why do taxa go extinct at different rates?

Two studies

Mammals

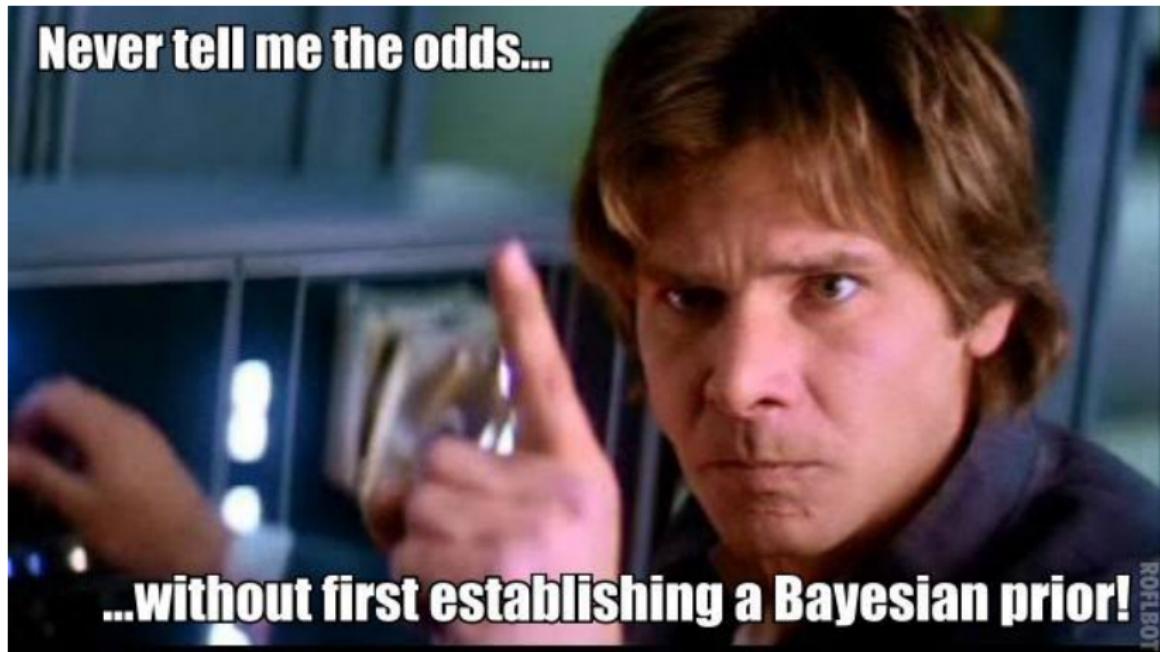


Brachiopods



(Immersion Imagery, Shutterstock)

Hierarchical Bayesian modeling



(www.countbayesie.com)

First things first...

(Some) notational definitions to help navigate

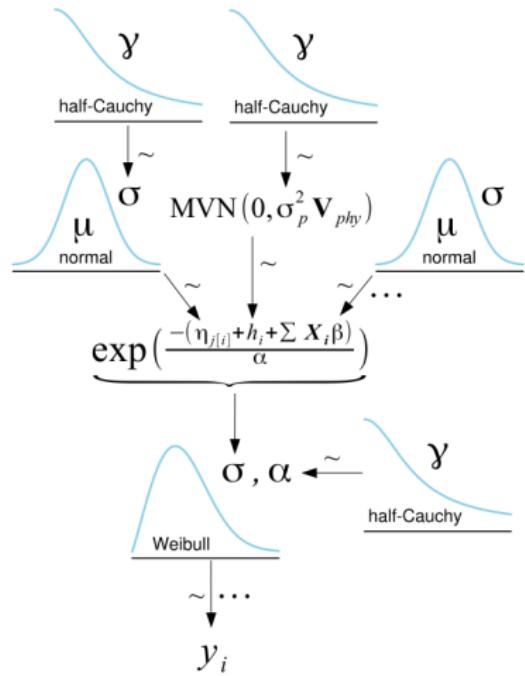
- ▶ y_i : duration of taxon i
- ▶ \mathbf{X} : $n \times k$ matrix of covariates
- ▶ \sim : rhs stochastically distributed as lhs
- ▶ β : regression coefficient (covariate effect)
- ▶ $j[i]$: taxon i belongs to group j

Study: mammal species duration

Questions

- ▶ How do the covariates of interest affect extinction risk?
 - ▶ dietary and locomotor category,
bioprovince occupancy, body size
- ▶ What is the relative contribution of temporal and phylogenetic structure on extinction risk?
- ▶ How do the identified time-invariant effects compare to modern determinates of extinction risk?

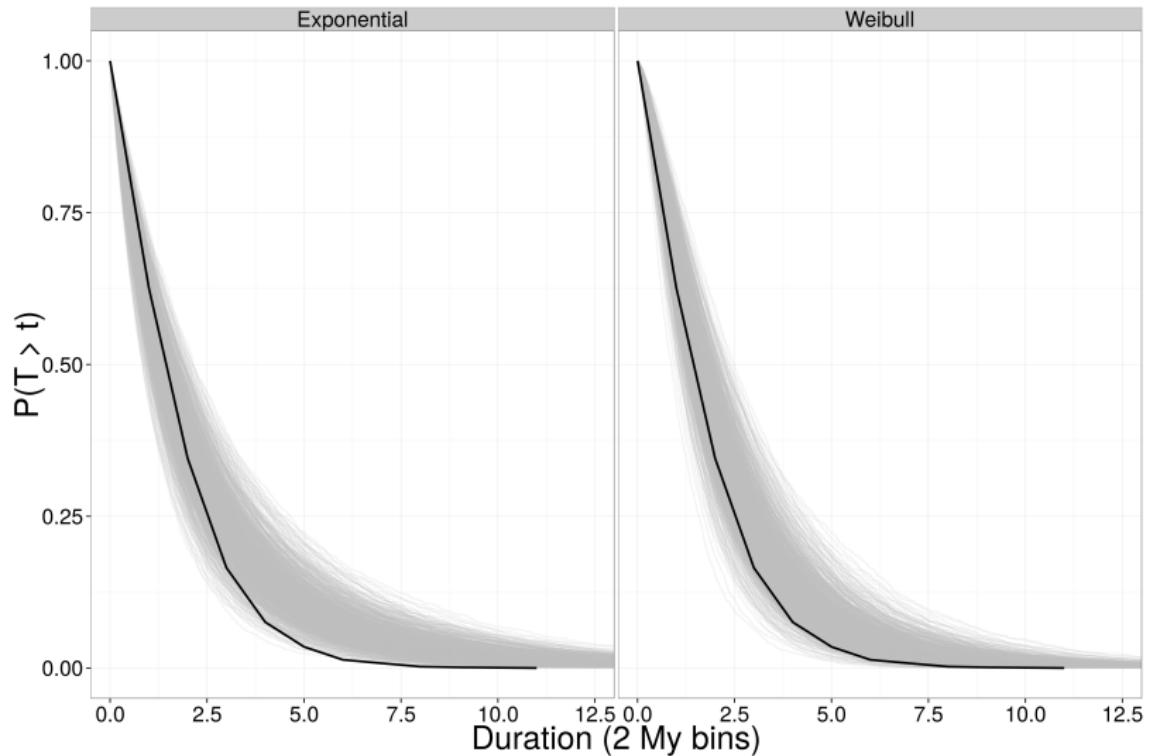
Model of mammal species survival



non-nested varying intercept

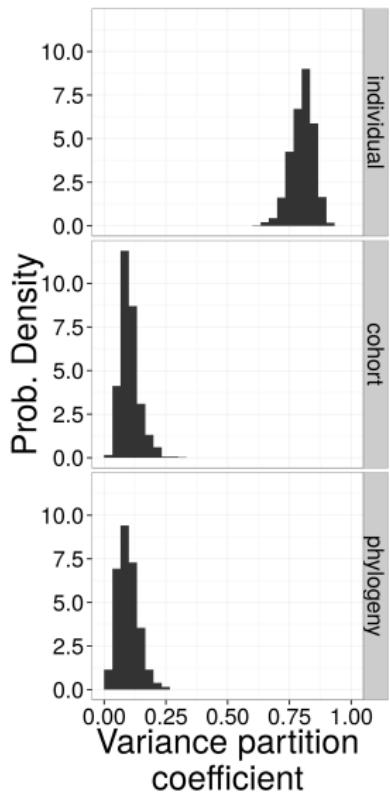
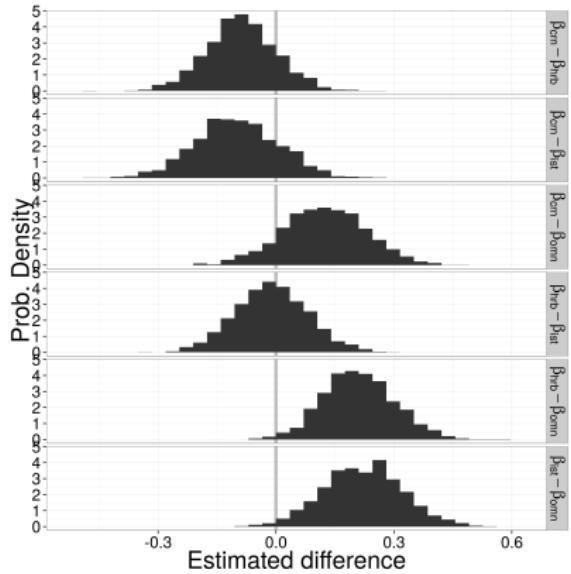
- ▶ origination cohort
($\eta_{j[i]}$ for $j = 1, \dots, J$)
 - ▶ exchangeable; $\mathcal{N}(0, \sigma_\eta)$
- ▶ phylogenetic position
(h_i for $i = 1, \dots, N$)
 - ▶ supertree
(mostly taxonomy)
 - ▶ mbl scaling;
resolved based on FAD
 - ▶ Brownian motion

Results



(Smits, Submitted)

Results



(Smits, Submitted)

Study: brachiopod genus duration

Questions

- ▶ How do the covariates of interest affect extinction risk?
 - ▶ geographic range, environmental affinity, body size
- ▶ How do these effects vary between origination cohorts?
- ▶ How do changes in trait-based effects covary with changes in baseline extinction risk?

Model of brachiopod genus survival

$$y_i \sim \text{Weibull}(\alpha, \sigma_i)$$

$$\sigma_i = \exp\left(\frac{-(\mathbf{X}_i \mathbf{B}_{j[i]})}{\alpha}\right)$$

$$\mathbf{B}_j \sim \text{MVN}(\vec{\mu}, \Sigma)$$

$$\Sigma = \text{Diag}(\vec{\tau}) \Omega \text{Diag}(\vec{\tau})$$

$$\alpha \sim C^+(2)$$

$$\mu_\kappa \sim \mathcal{N}(0, 5) \text{ for } \kappa \in 1 : k$$

$$\tau_\kappa \sim C^+(1) \text{ for } \kappa \in 1 : k$$

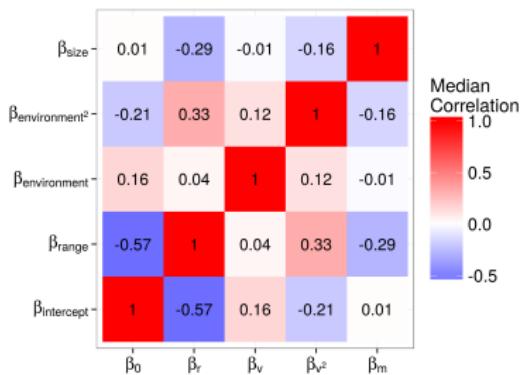
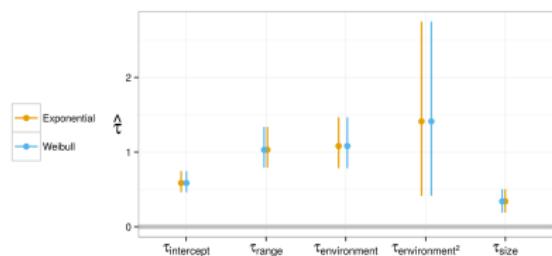
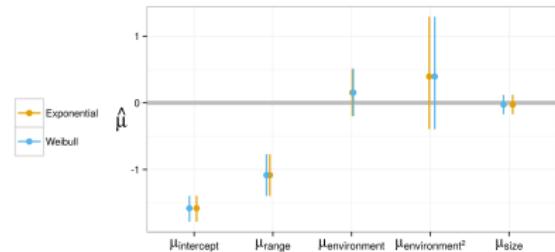
$$\Omega \sim \text{LKJ}(2).$$

Unreadable. I know.

Key details

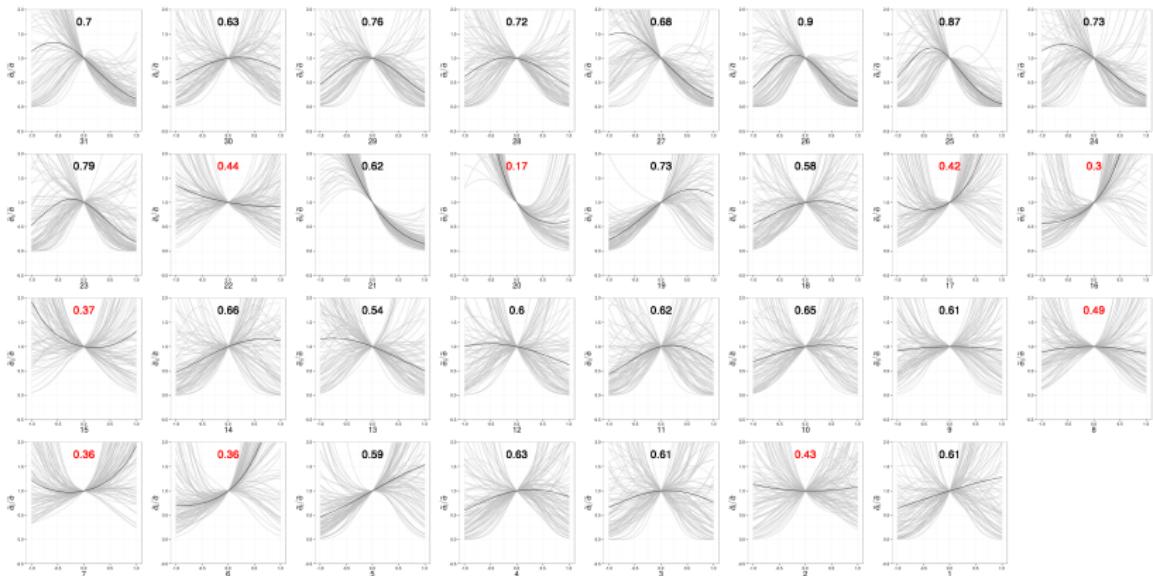
- ▶ varying slopes,
varying intercepts
- ▶ \mathbf{B} : $k \times J$ matrix of β -s
- ▶ $\vec{\mu}$: hierarchical means of β -s
- ▶ Σ : covariance matrix of
(hierarchical) β -s
- ▶ $\vec{\tau}$: vector of hierarchical
scales (partial pooling)
- ▶ Ω : correlation matrix of
(hierarchical) β -s
- ▶ model uncertainty in
environmental affinity
(not shown)

Results



(Smits, *In prep.*)

Results



(Smits, In prep.)

Summary

Mammals



Brachiopods



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