

# How do species traits affect extinction risk?

New approaches to old questions.

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The Paleobiology Database  
revealing the history of life

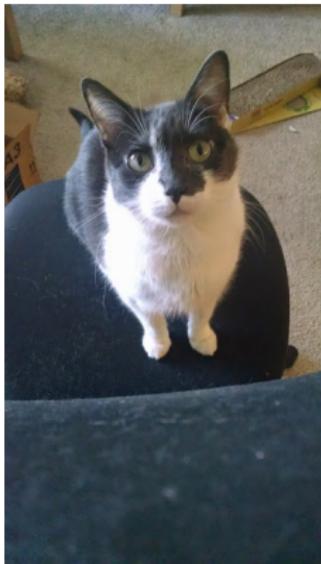


## Question

Why do taxa go extinct at different rates?

# Two studies

## Mammals

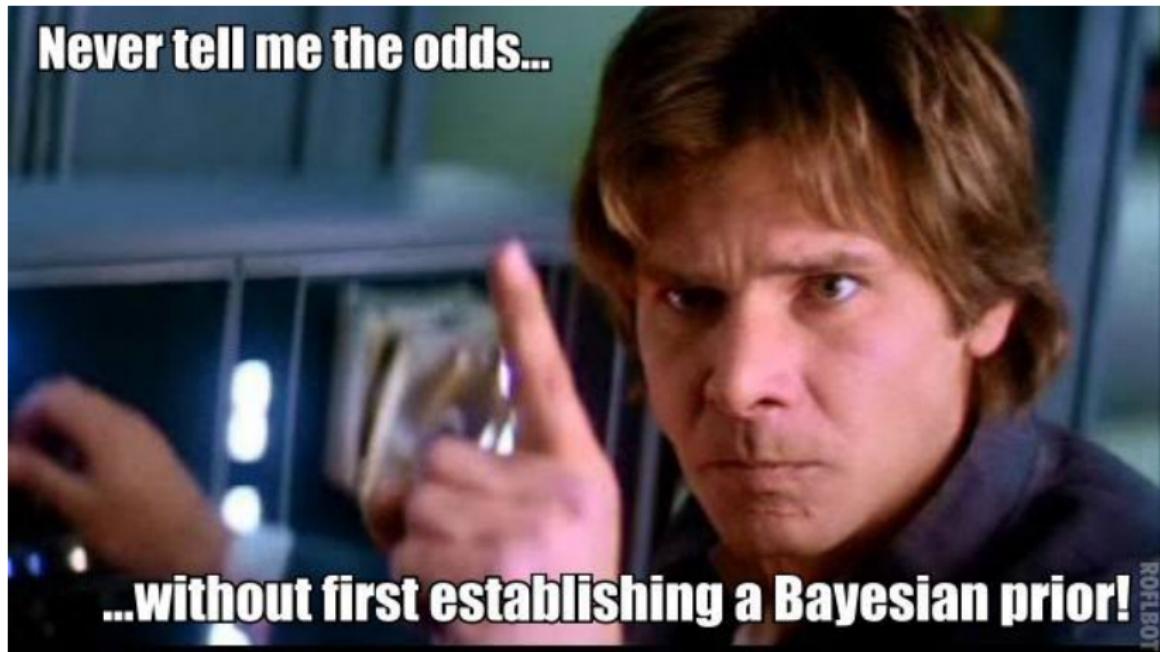


## Brachiopods



(Immersion Imagery, Shutterstock)

# Hierarchical Bayesian modeling



([www.countbayesie.com](http://www.countbayesie.com))

# First things first...

(Some) notational definitions to help navigate

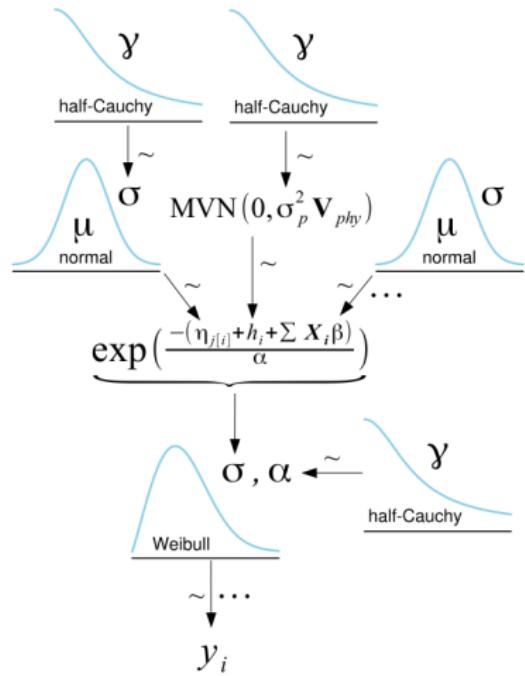
- ▶  $y_i$ : duration of taxon  $i$
- ▶  $\mathbf{X}$ :  $n \times k$  matrix of covariates
- ▶  $\sim$ : rhs stochastically distributed as lhs
- ▶  $\beta$ : regression coefficient (covariate effect)
- ▶  $j[i]$ : taxon  $i$  belongs to group  $j$

# 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?

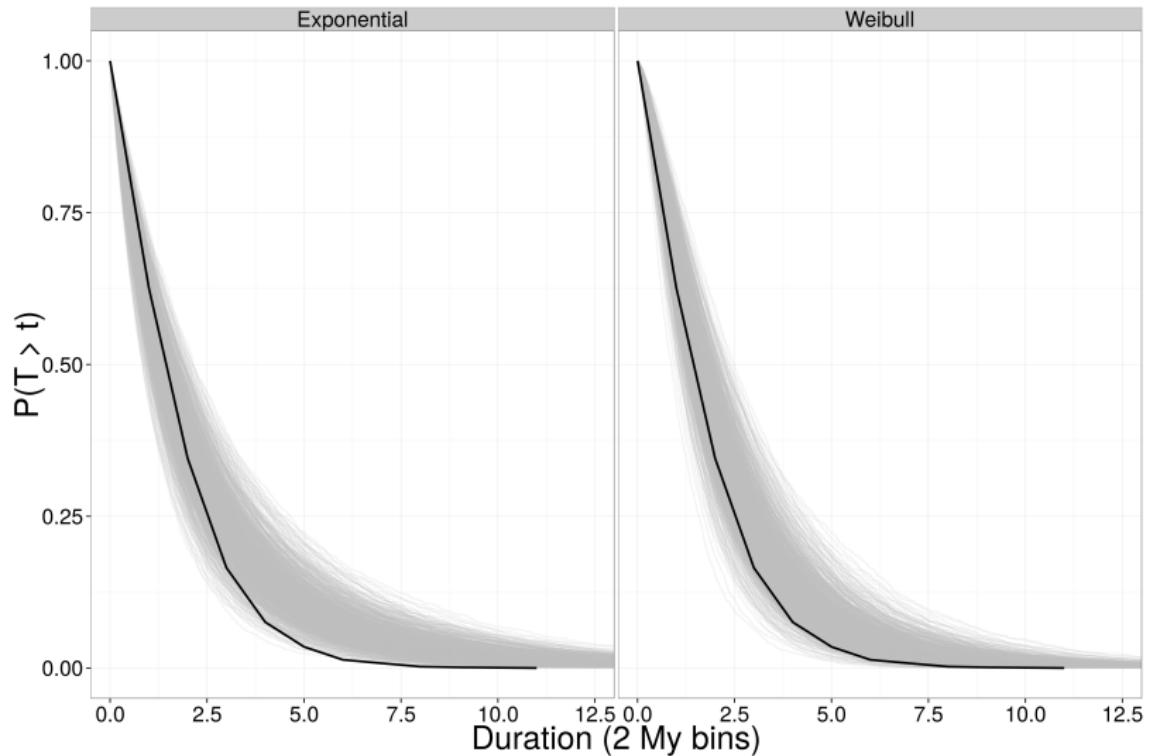
# Model of mammal species survival



non-nested varying intercept

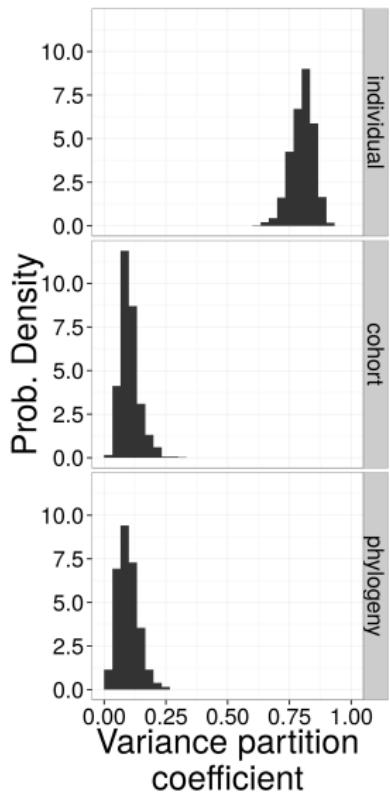
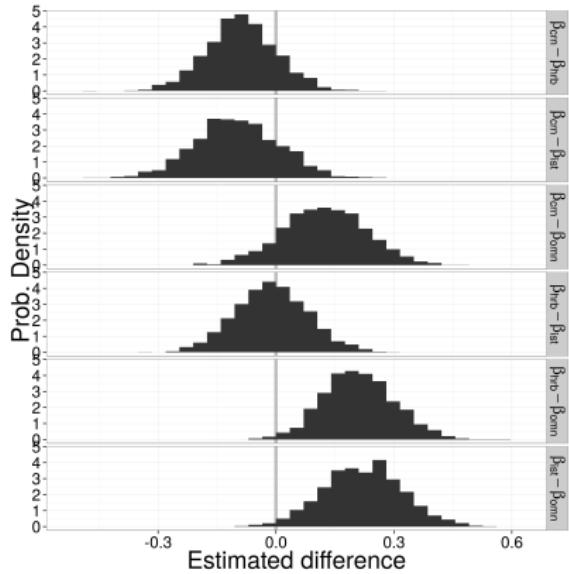
- ▶ origination cohort  
( $\eta_{j|i}$  for  $j = 1, \dots, J$ )
  - ▶ exchangeable;  $\mathcal{N}(0, \sigma_\eta)$
- ▶ phylogenetic position  
( $h_i$  for  $i = 1, \dots, N$ )
  - ▶ supertree  
(mostly taxonomy)
  - ▶ mbl scaling;  
resolved based on FAD
  - ▶ Brownian motion

# 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 trait-based effects vary between origination cohorts?
- ▶ How do these trait-based changes relate to changes in baseline extinction risk?

# Model of brachiopod genus survival

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

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

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

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

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

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

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

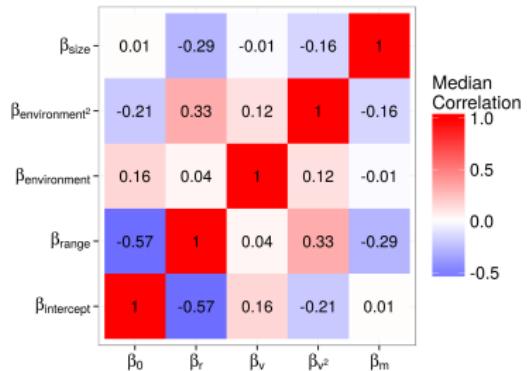
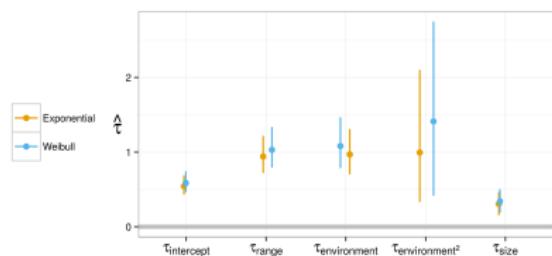
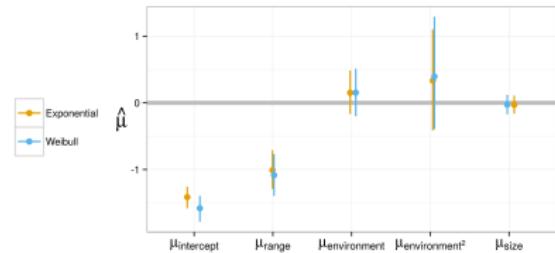
$$\Omega \sim \text{LKJ}(2).$$

Unreadable. I know.

## Key details

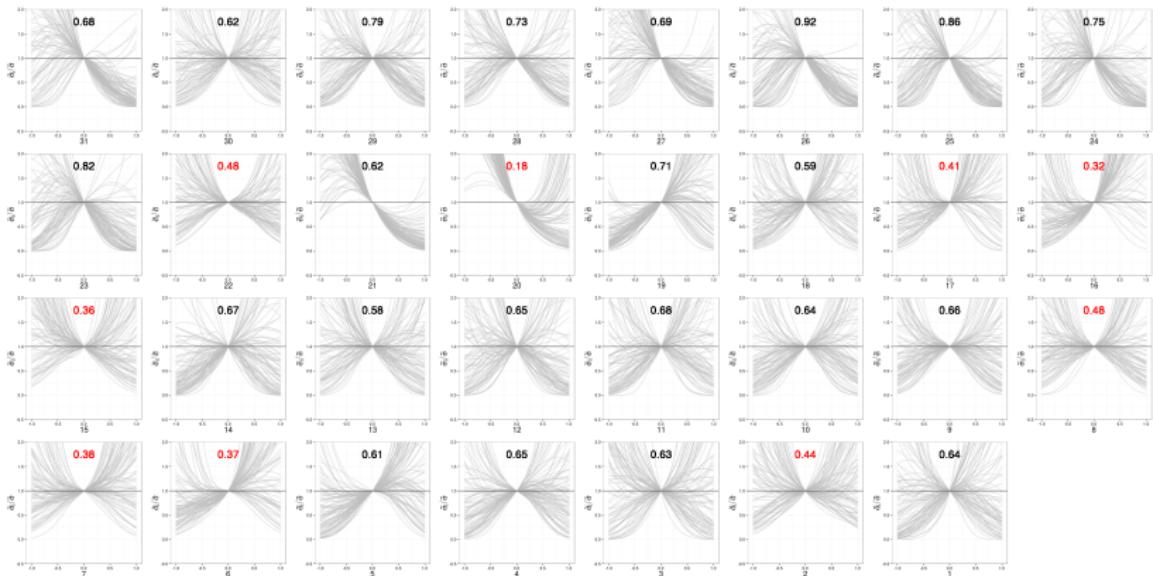
- ▶ varying slopes,  
varying intercepts
- ▶  $\mathbf{B}$ :  $k \times J$  matrix of  $\beta$ -s
- ▶  $\vec{\mu}$ : hierarchical means of  $\beta$ -s
- ▶  $\Sigma$ : covariance matrix of  
(hierarchical)  $\beta$ -s
- ▶  $\vec{\tau}$ : vector of hierarchical  
scales (partial pooling)
- ▶  $\Omega$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

# Results



(Smits, *In prep.*)

# Results



(Smits, In prep.)

# Summary

**Brachiopods**



**Mammals**



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