# How do species traits affect extinction risk?

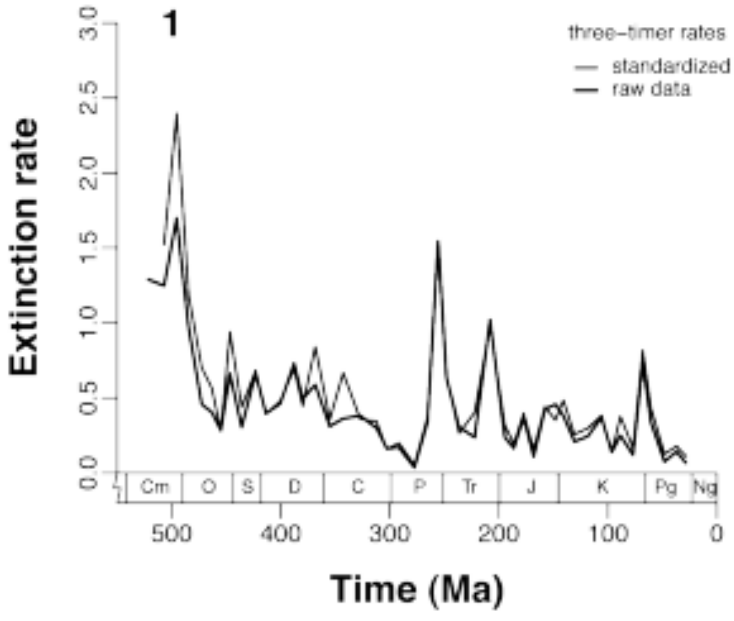
## New approaches to old questions.

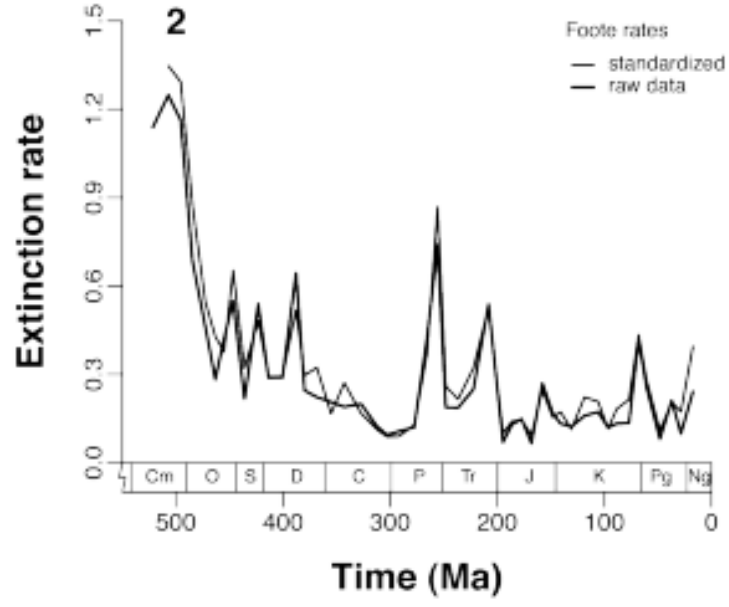
Peter D Smits

Committee on Evolutionary Biology

The Paleobiology Database

revealing the history of life


1
three−timer rates
standardized
raw data
Extinction rate
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Cm
O
S
D
C
P
Tr
J
K
Pg
Ng
500
400
300
200
100
0
Time (Ma)


2
Foote rates
standardized
raw data
Extinction rate
0.0
0.3
0.6
0.9
1.2
1.5
Cm
O
S
D
C
P
Tr
J
K
Pg
Ng
500
400
300
200
100
0
Time (Ma)

## Question

Why do taxa go extinct at different rates?

# Two studies

**Brachiopods**

**Mammals**

# Hierarchical Bayesian modeling


(www.countbayesie.com)

# First things first. . .

## (Some) notational definitions to help navigate

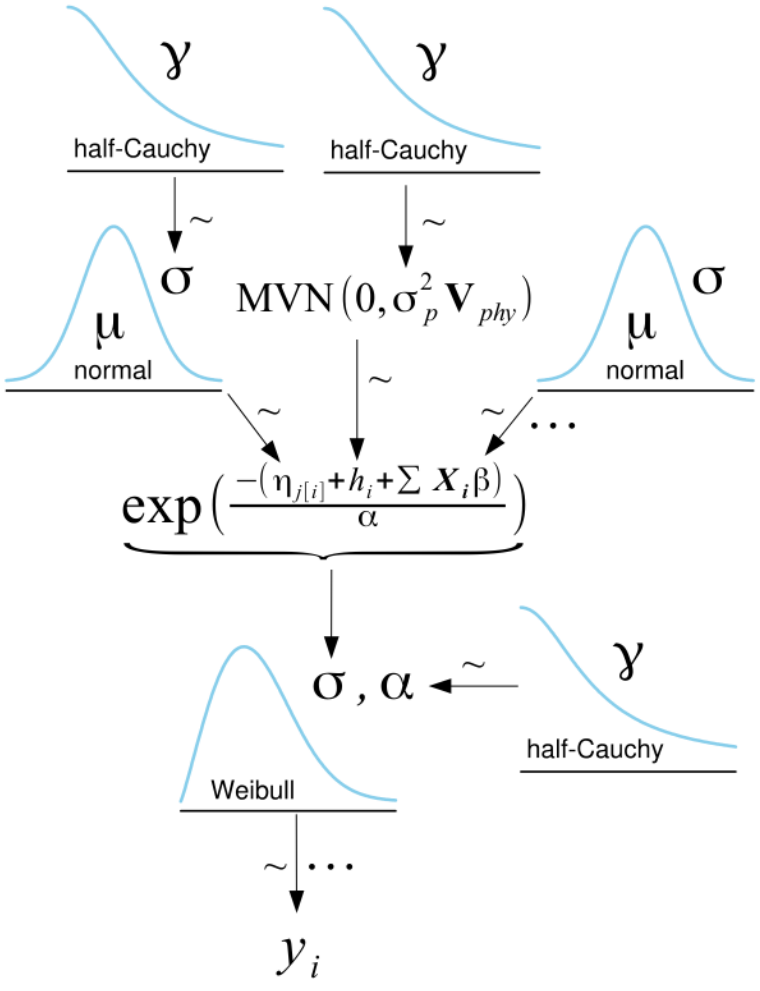
- $y_i$: duration of taxon $i$
- $\mathbf{X}$: $n \times k$ matrix of covariates
- $\sim$: rhs stochastically distributed as lhs
- $\beta$: regression coefficient (covariate effect)
- $j[i]$: taxon $i$ belongs to group $j$

# 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 $j = 1, \ldots, J$)
  - exchangable; $\mathcal{N}(0, \sigma_\eta)$
- phylogenetic position ($h_i$ for $i = 1, \ldots, N$)
  - supertree (mostly taxonomy)
  - mbl scaling; resolved based on FAD
  - Brownian motion

# Results

# 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

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

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

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

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

$$\alpha \sim \text{C}^+(2)$$

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

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

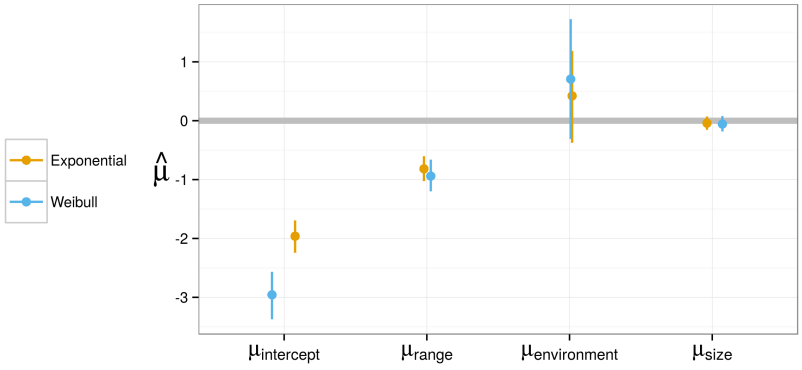
$$\mathbf{\Omega} \sim \text{LKJ}(2).$$

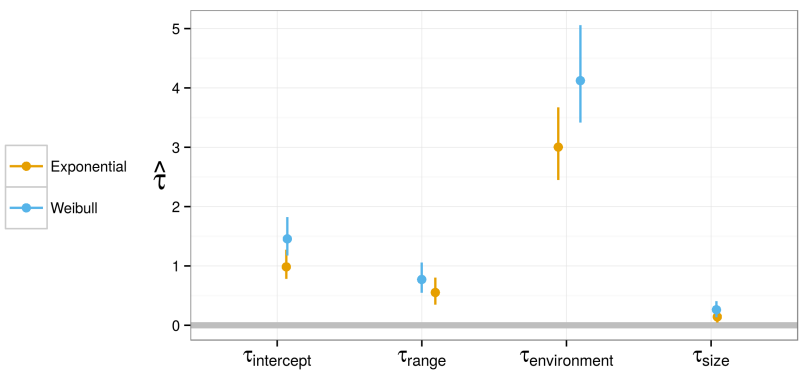
Unreadable. I know.

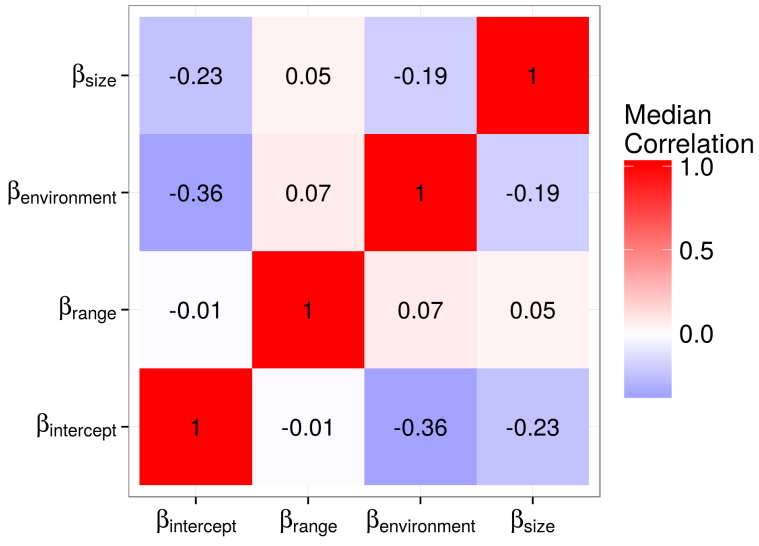
Key details

- varying slopes, varying intercepts
- $\vec{\mu}$: 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

# Results


Exponential
Weibull
$\hat{\mu}$
1
0
-1
-2
-3
$\mu_{intercept}$
$\mu_{range}$
$\mu_{environment}$
$\mu_{size}$


Exponential
Weibull
$\hat{\tau}$
5
4
3
2
1
0
$\tau_{intercept}$
$\tau_{range}$
$\tau_{environment}$
$\tau_{size}$


$\beta_{size}$
$\beta_{environment}$
$\beta_{range}$
$\beta_{intercept}$
-0.23
0.05
-0.19
1
-0.36
0.07
1
-0.19
-0.01
1
0.07
0.05
1
-0.01
-0.36
-0.23
$\beta_{intercept}$
$\beta_{range}$
$\beta_{environment}$
$\beta_{size}$
Median Correlation
1.0
0.5
0.0

# Summary

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