

# Cenozoic mammals and the biology of extinction

Peter D Smits

Committee on Evolutionary Biology, University of Chicago

June 9, 2014

*All species that have ever lived are, to a first approximation, dead.*

*(Raup 1986 The Nemesis Affair)*

## Question

Why do certain taxa go extinct while others do not?

# Modes of extinction

Field of Bullets      –      Wanton      –      Fair Game

(Raup 1991 Extinction: Bad Genes or Bad Luck?)

# In context of this study

Rephrased

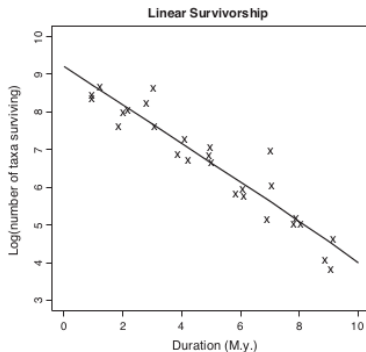
How does a taxon's **adaptive zone** affect **extinction risk**?

# Van Valen's observation

## Law of Constant Extinction

Extinction rate, in a given adaptive zone, is taxon-age independent.

(Van Valen 1973 *Evol. Theory*)



(Liow et al. 2011 *TREE*)

# Formalization of Van Valen

## Law of Constant Extinction

$$T \sim \text{Exp}(\lambda)$$

$T$ : survival time

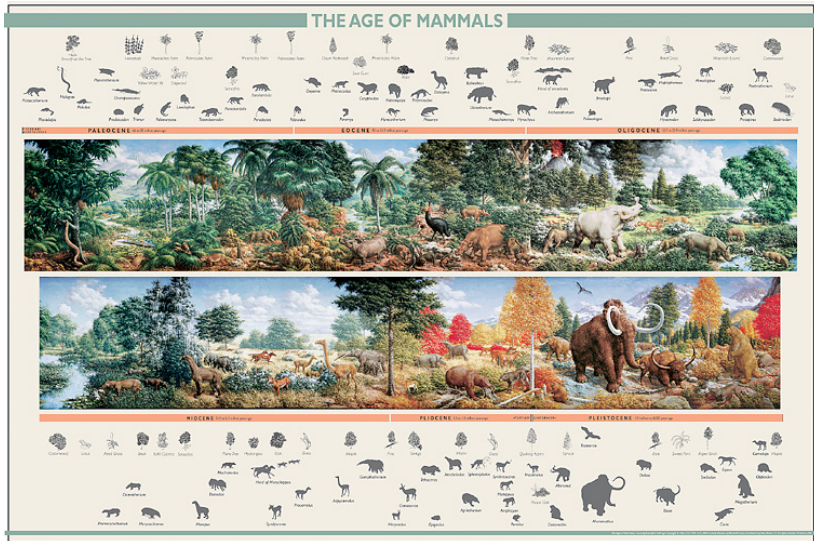
$\lambda$ : expected number of  
extinctions per unit time

## Questions

- ▶ Do interactions involved in environmental preference predict differential survival?
  - ▶ Is survival best modeled by a single interactor or multiple interactors?
  - ▶ How do factors, such as climate, contribute?
- ▶ Is extinction taxon-age independent or dependent?
- ▶ Do genera and species have fundamentally different survival distributions?



# Mammals



(Yale Peabody Museum)

# Regions

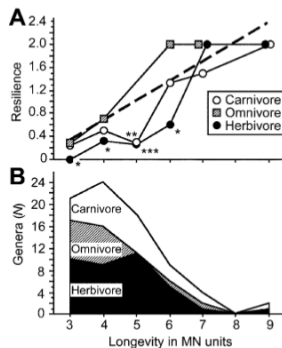
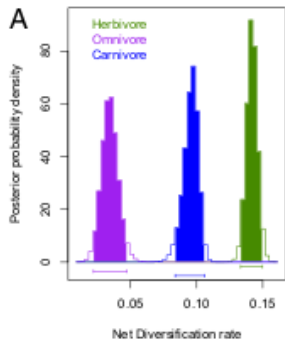


North America:  
2366 species, 1003 genera



Europe:  
1767 species, 658 genera

# Diet



carnivore, herbivore, omnivore, insectivore

herbivore > carnivore

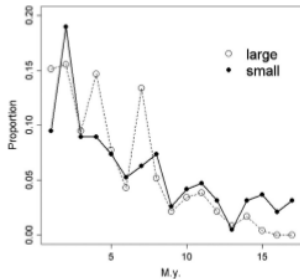
omnivore  $\simeq$  carnivore

insectivore ?

ground dwelling, scansorial,  
arboreal

- ▶ ground dwelling  $>$  arboreal
- ▶ scansorial  $\simeq$  ground dwelling

# Body size



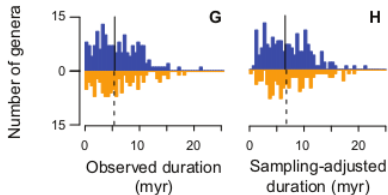
↑ mass, ↑ range size, ↑ survival

OR

↑ mass, ↓ reproductive rate, ↓ survival

OR

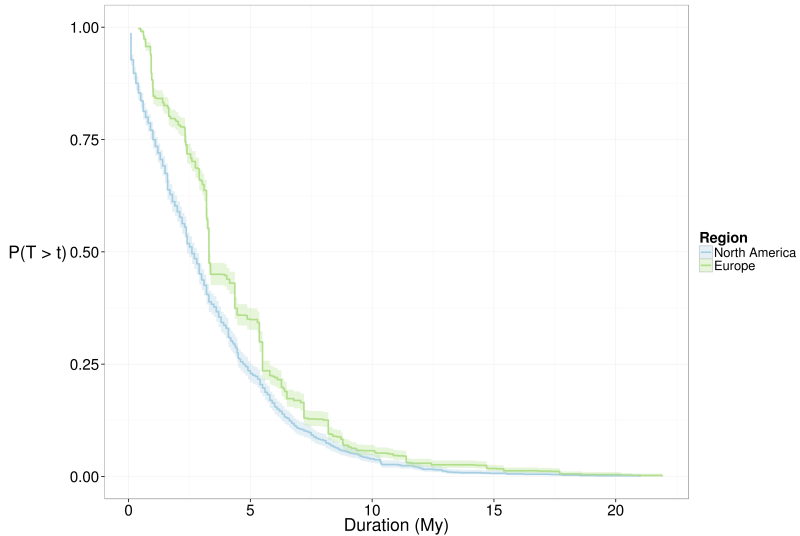
no effect



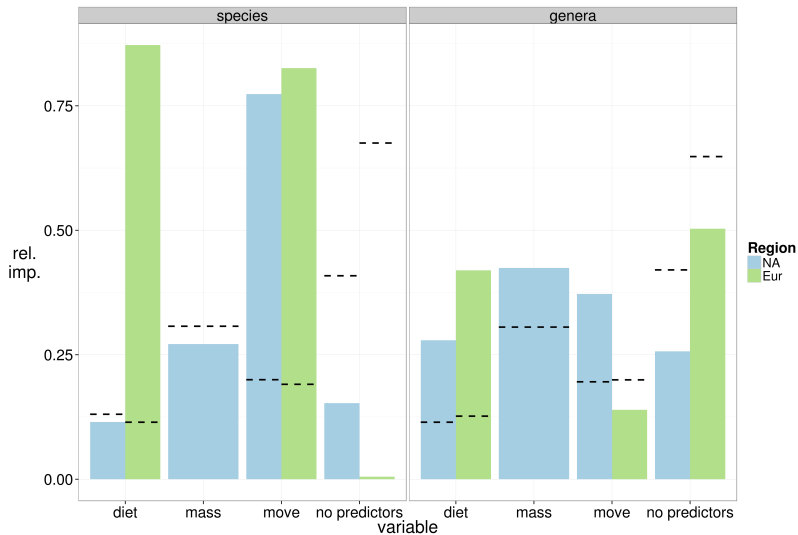
# Analysis and inference

- ▶ PBDB occurrences
- ▶ age  $\sim$  Exponential or Weibull
- ▶  $\lambda \propto$  traits,  $k$  constant
- ▶ range in/out taxa  
right censored
- ▶ maxLik approach,  
multi-model inference

# NP regional survival curves

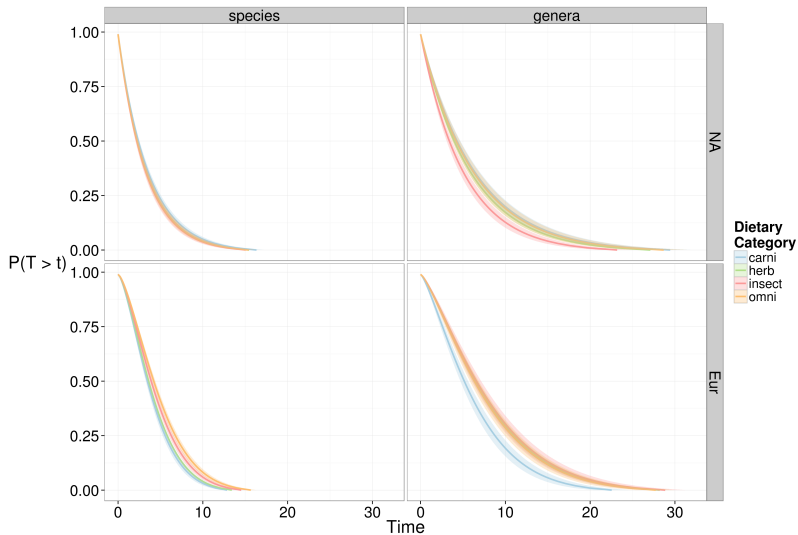


# Variable importance

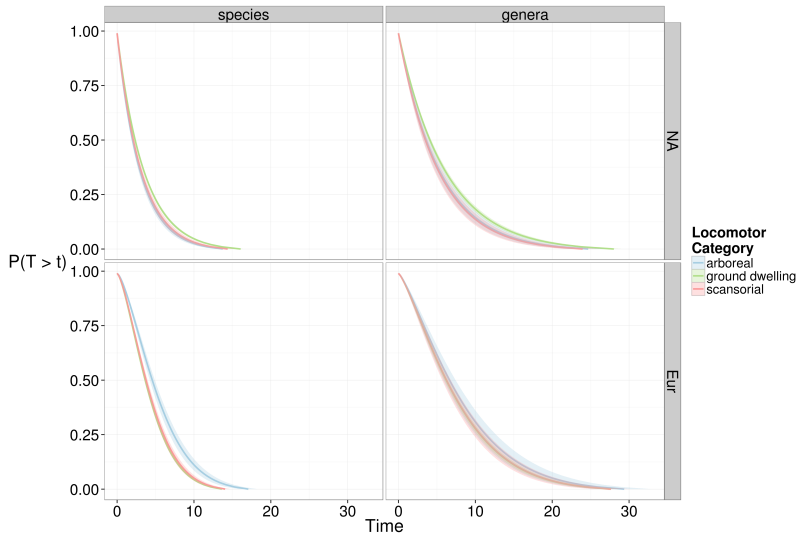




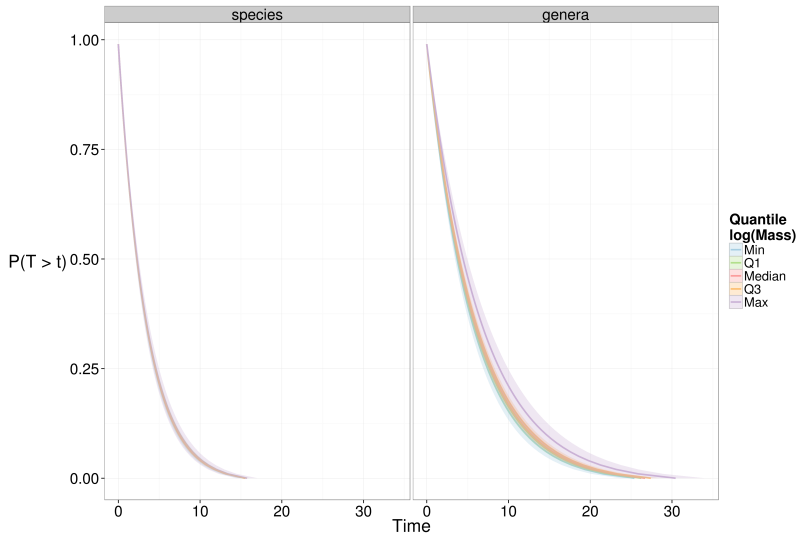
# Effect of diet



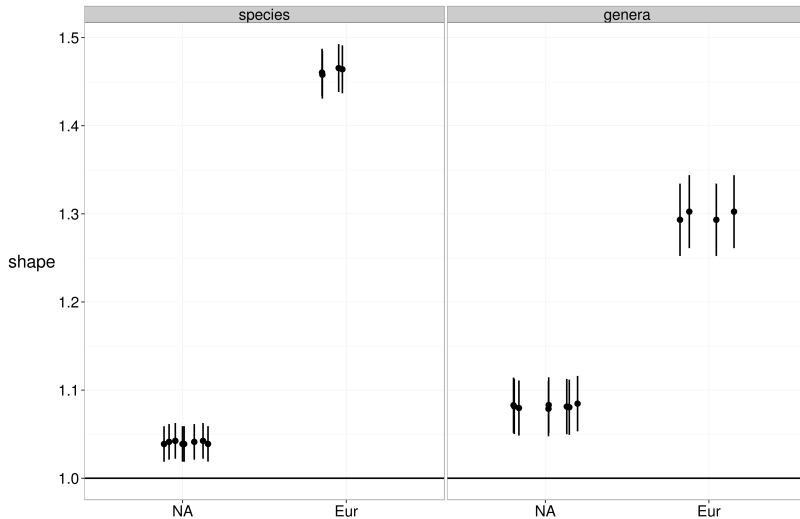
# Effect of locomotion



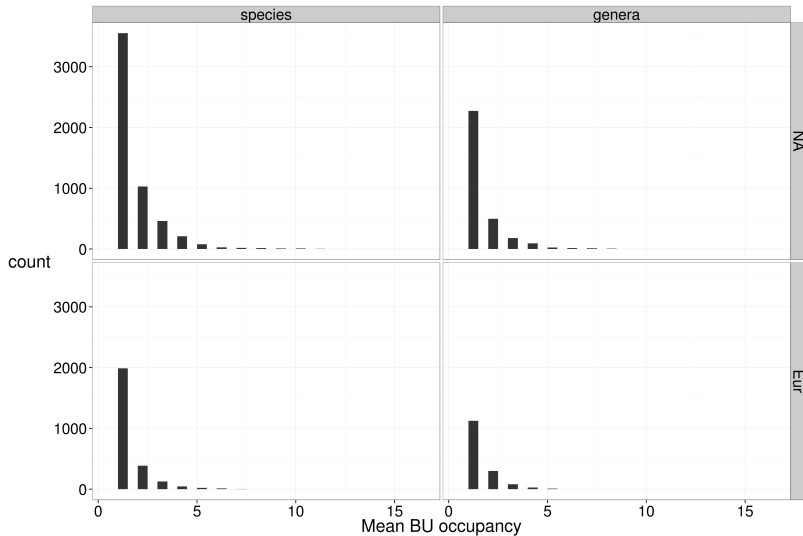
# Effect of mass



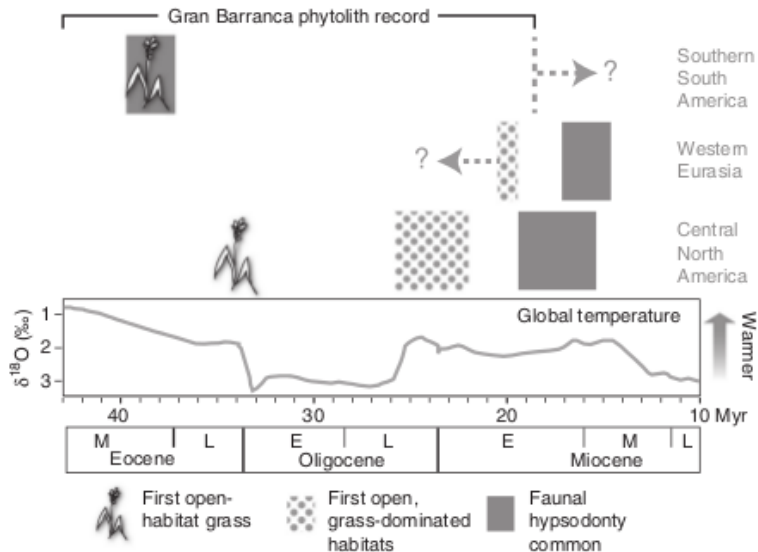
# Time dependence



# The Elephant in the Range



# Climate



(Strömberg *et al.* 2013 *Nature Com.*)

# Laundry list of model improvements

- ▶ currently  $\hat{k} = c$ , future  $\hat{k} \approx$  CV climate and/or occupancy
- ▶ emergent properties
  - ▶ species:genus
  - ▶ trait dispersion ( $H(\text{diet})$ ,  $\text{Var}(\text{mass})$ , etc.)
- ▶ CAR prior on frailty using phylogenetic distance/VCV matrix
- ▶ incorporate duration uncertainty due to sampling

# Acknowledgements

## ▶ Committee

- ▶ Kenneth D. Angielczyk  
(co-advisor)
- ▶ Michael J. Foote  
(co-advisor)
- ▶ P. David Polly
- ▶ Richard H. Ree

## ▶ Discussion

- ▶ David Bapst, Megan Boatright, Ben Frable, Colin Kyle, Darcy Ross, Liz Sander
- ▶ John Alroy, Graeme Lloyd, Kathleen Ritterbush, Carl Simpson, Graham Slater



The **Field**  
Museum

