Cenozoic mammals and the biology of extinction

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Extinction

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

(Raup 1986 The Nemesis Affair)

Foundation

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

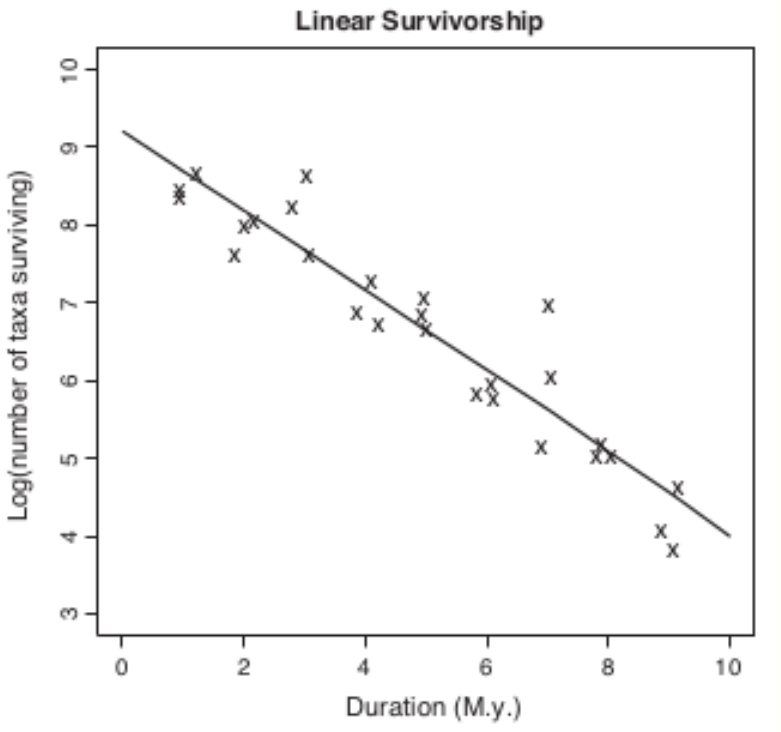
How does a taxon's adaptive zone affect extinction risk?

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

$T \sim Exp(\lambda)$

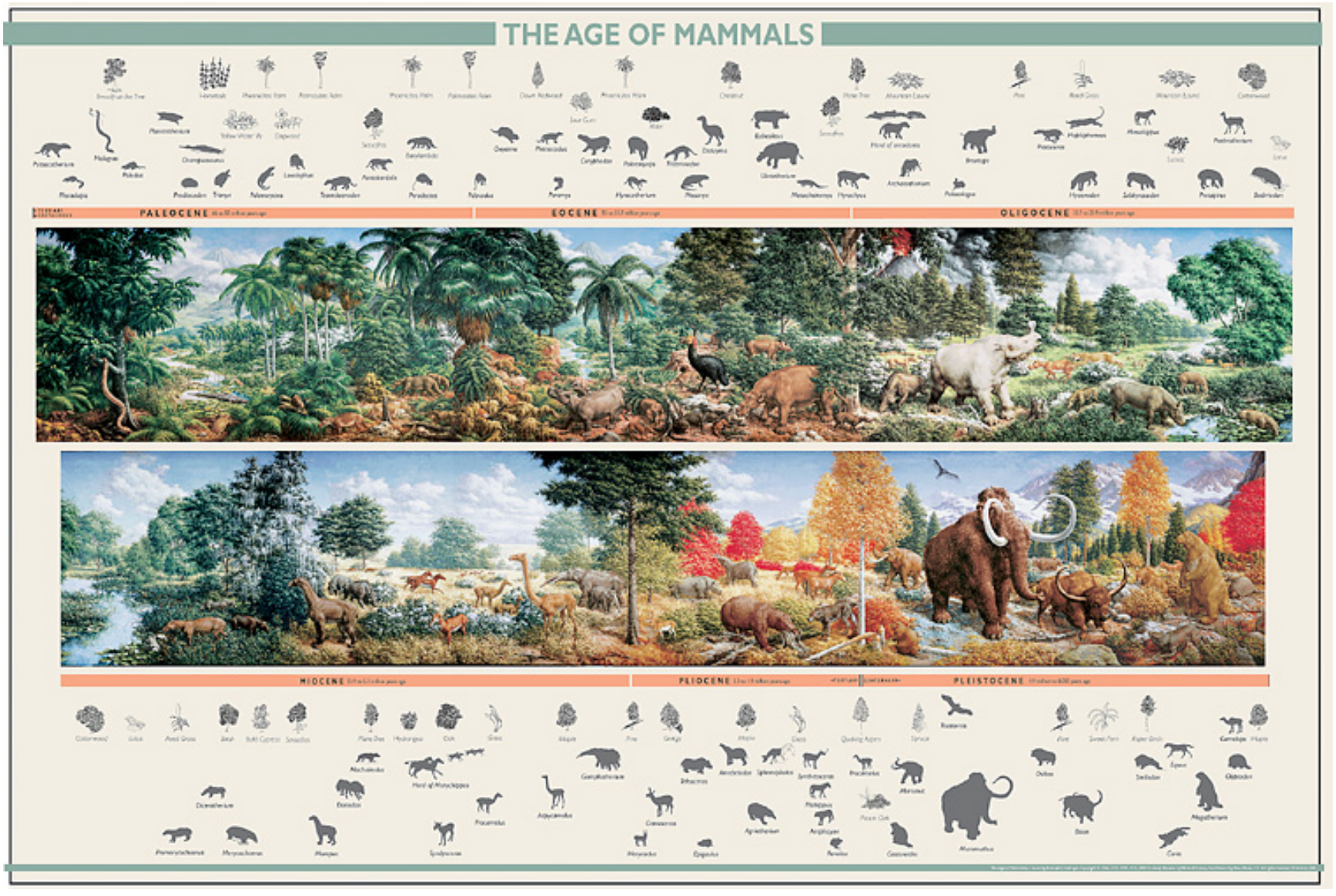
T: survival time
λ: expected number of extinctions per unit time

Biology and extinction

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



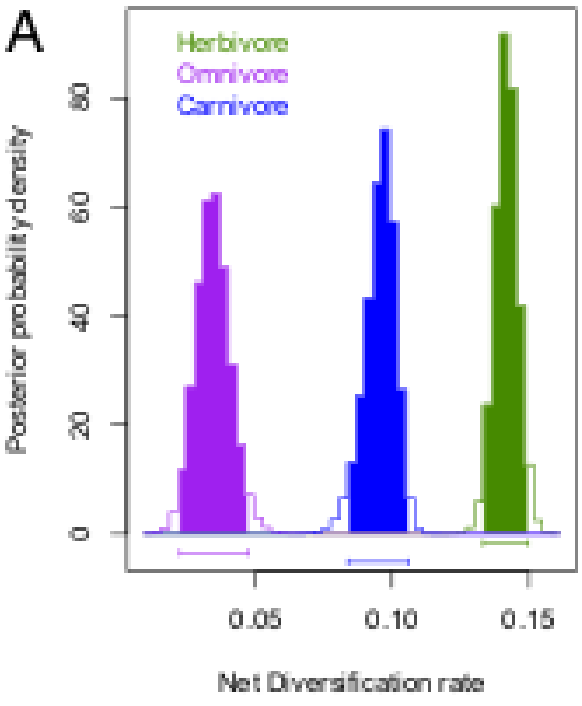
(Yale Peabody Museum)

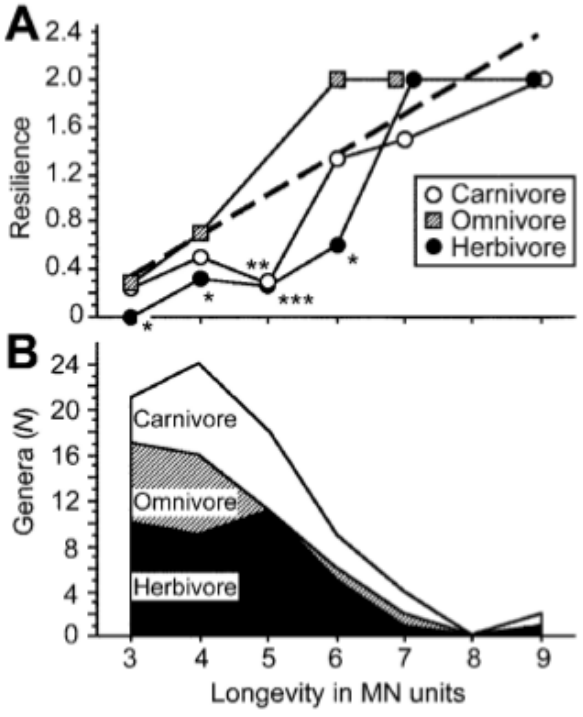
Regions

North America:
2366 species, 1003 genera

Europe:
1767 species, 658 genera

Diet





carnivore, herbivore, omnivore, insectivore

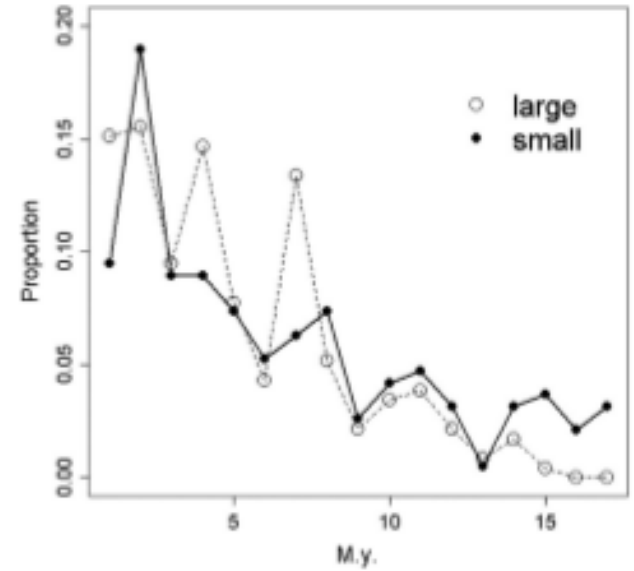
herbivore $>$ carnivore omnivore $\simeq$ carnivore insectivore ?

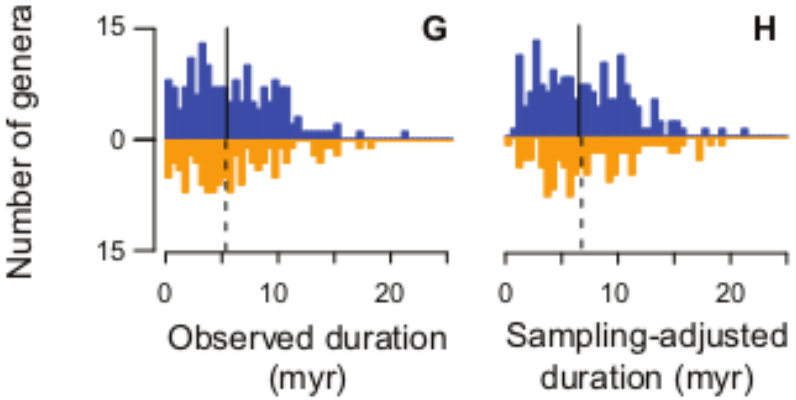
Locomotion

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

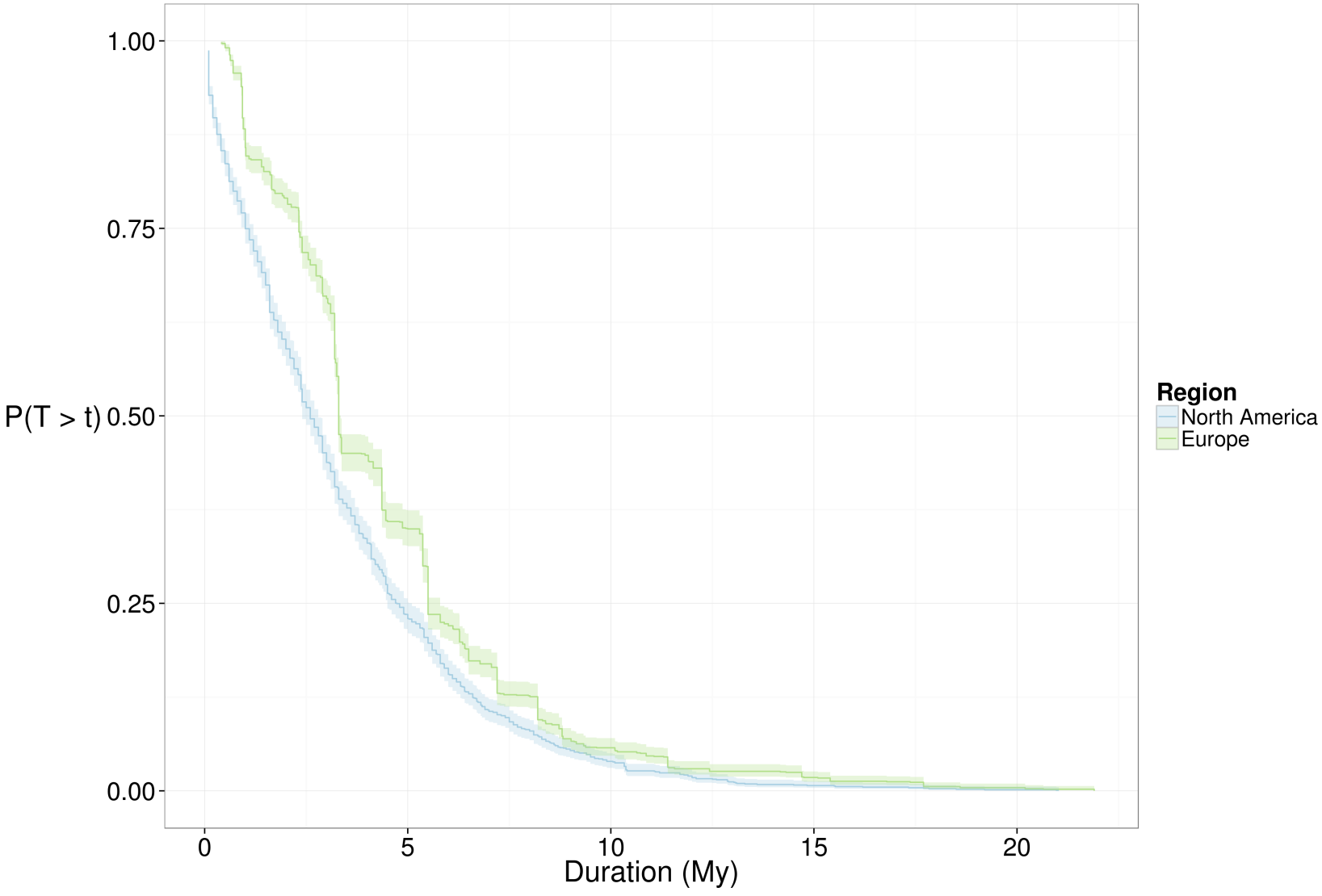
Survival analytical framework

age $\sim$ Exponential or Weibull

$\lambda \propto$ traits, k constant

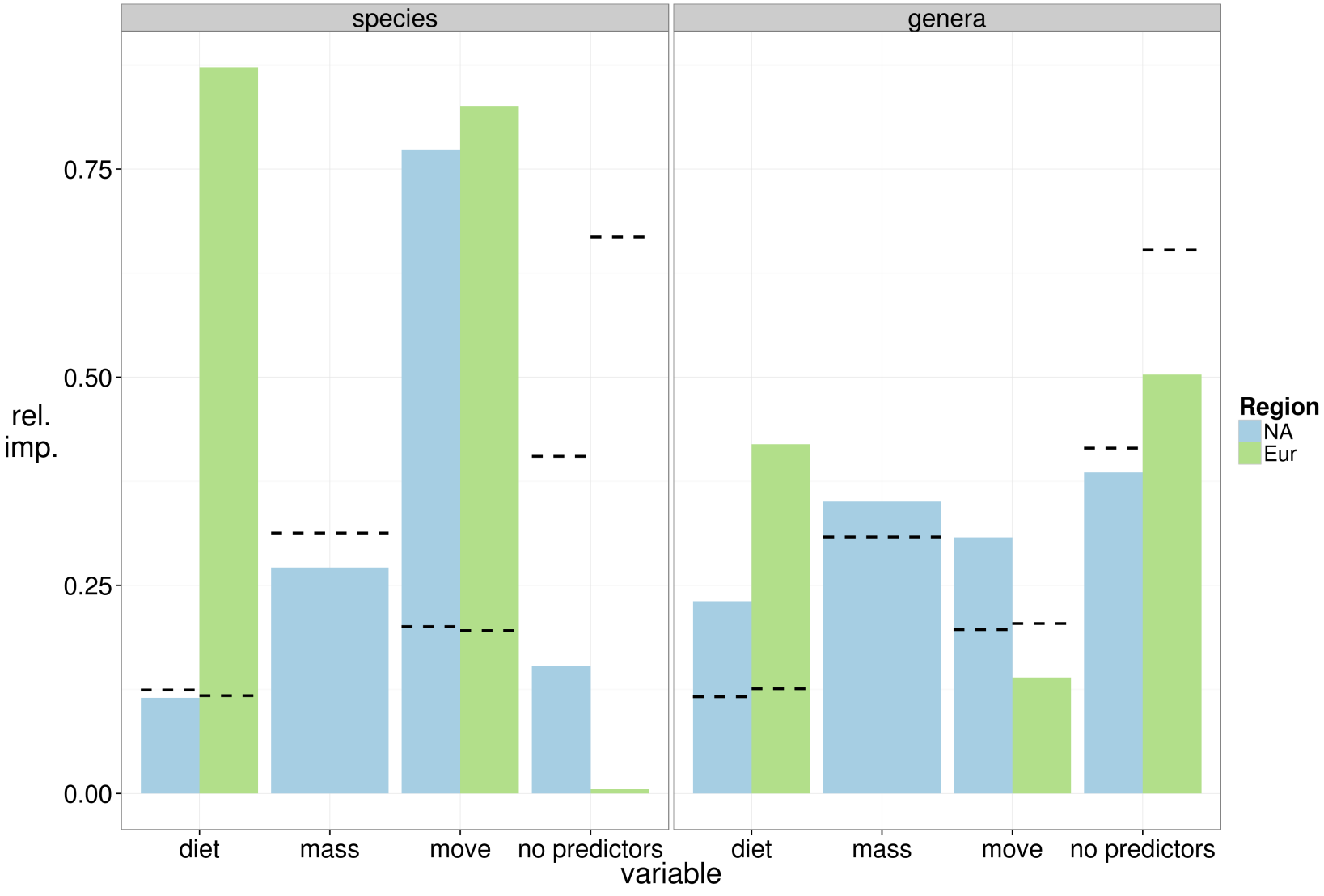
range in/out taxa right censored

NP regional survival curves

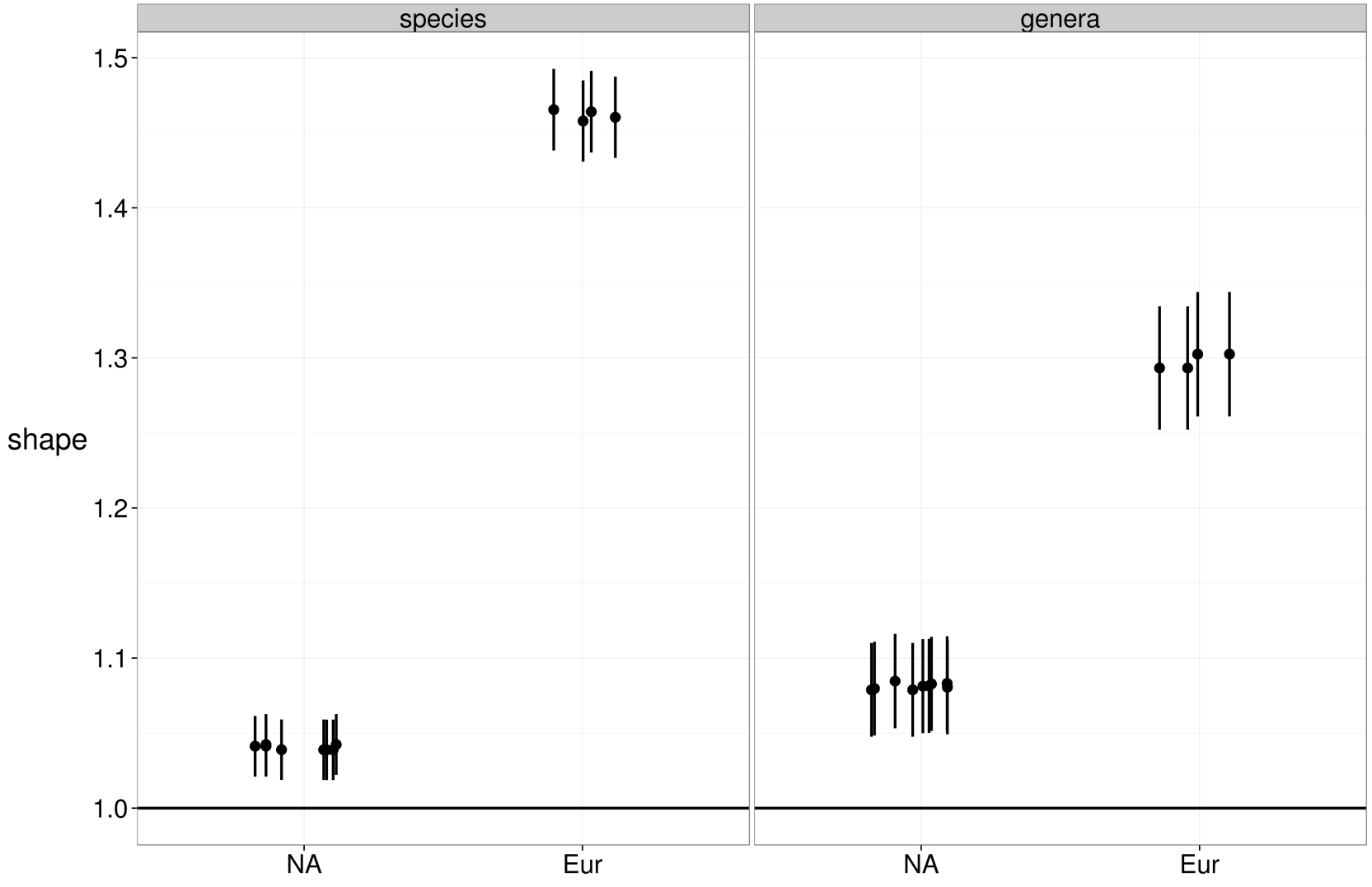


Model selection

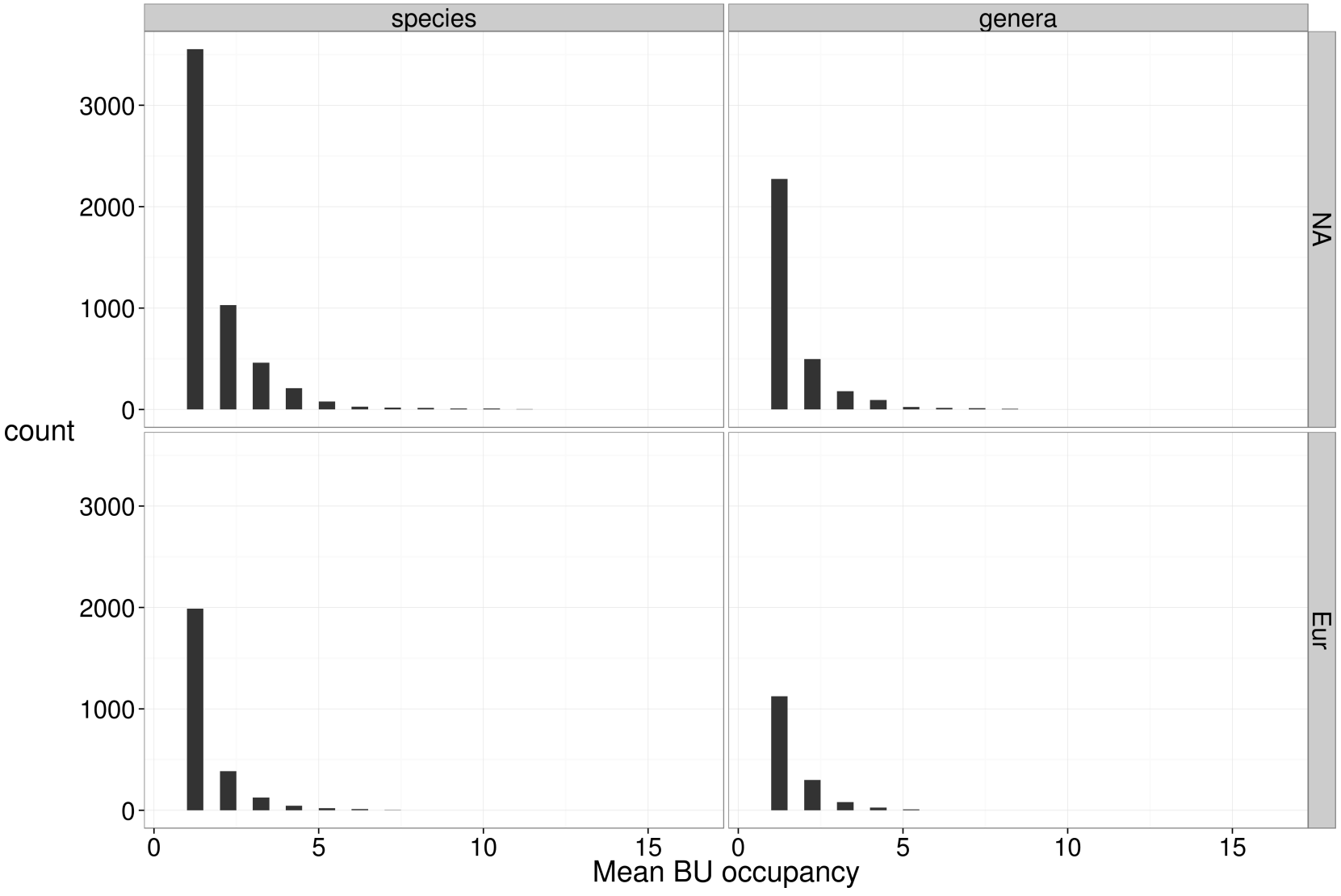
Variable importance



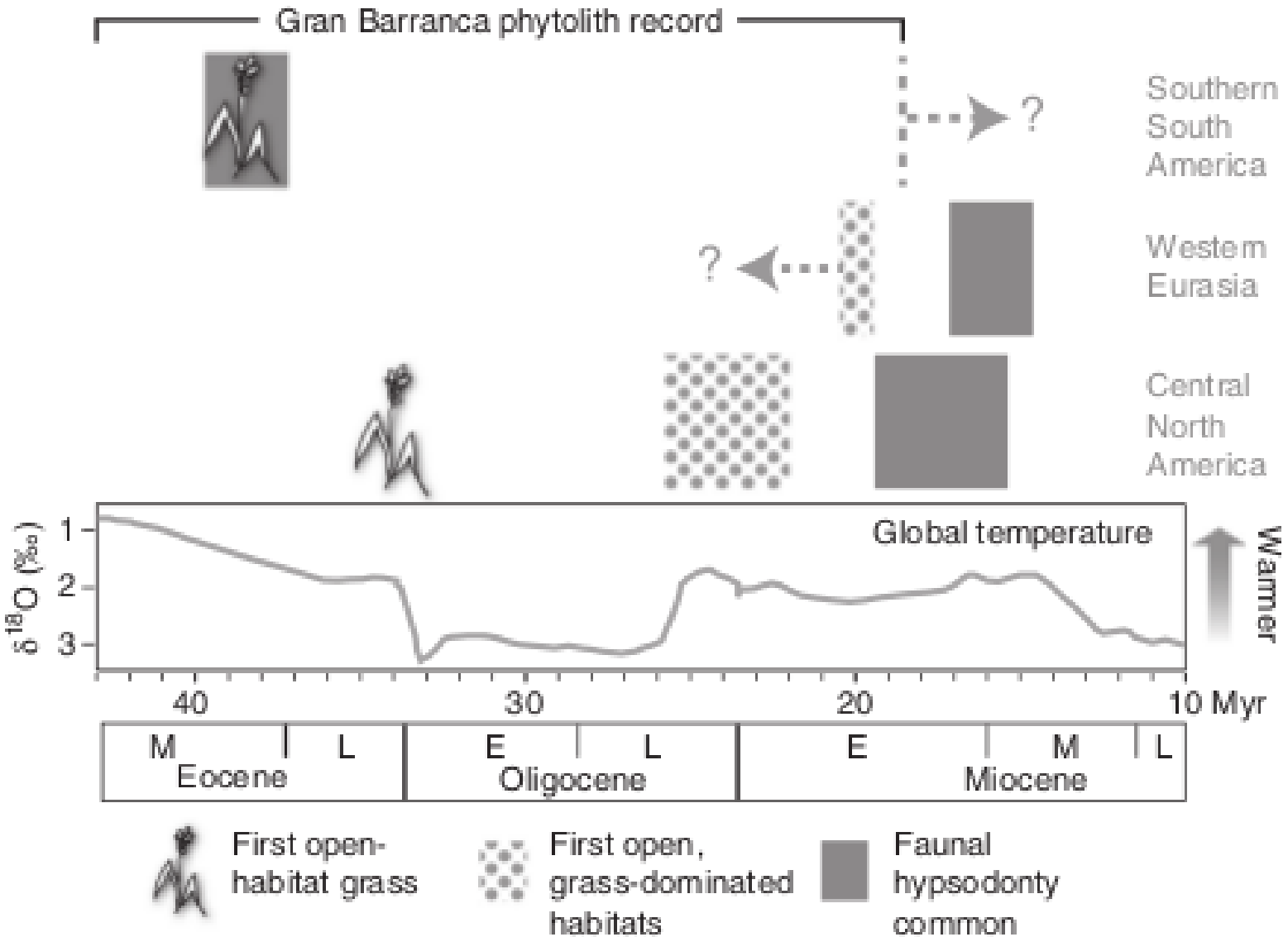
Time dependence



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
- generic level properties
  - species:genus
  - trait dispersion (H(diet), Var(mass), etc.)
- CAR prior on frailty using phylogenetic distance/VCV matrix
- incorporate duration uncertainty due to sampling

Acknowledgements

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The Field Museum

Fossilworks

Paleobiology Database