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

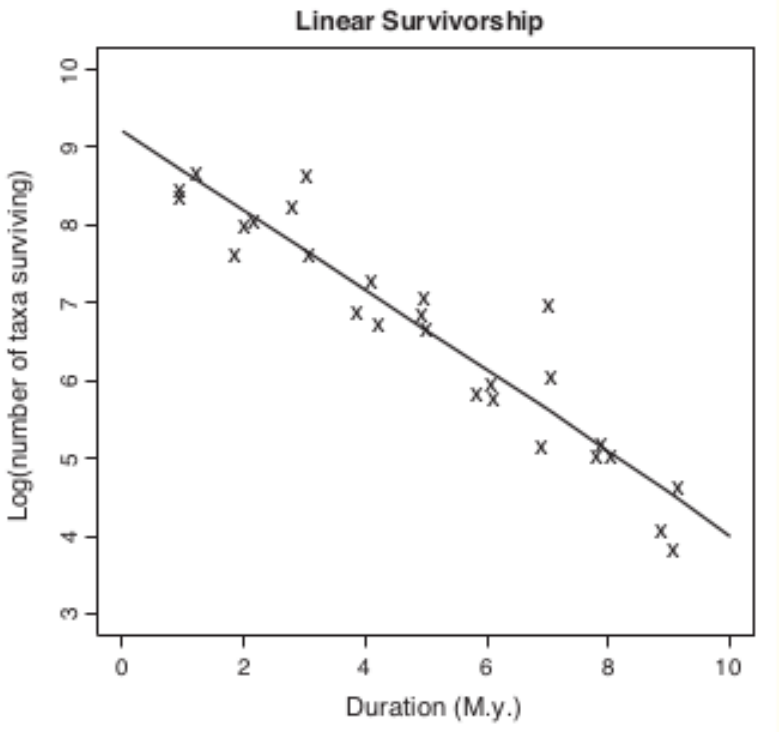
How does a taxon's adaptive zone affect extinction risk?

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

$T \sim Exp(\lambda)$

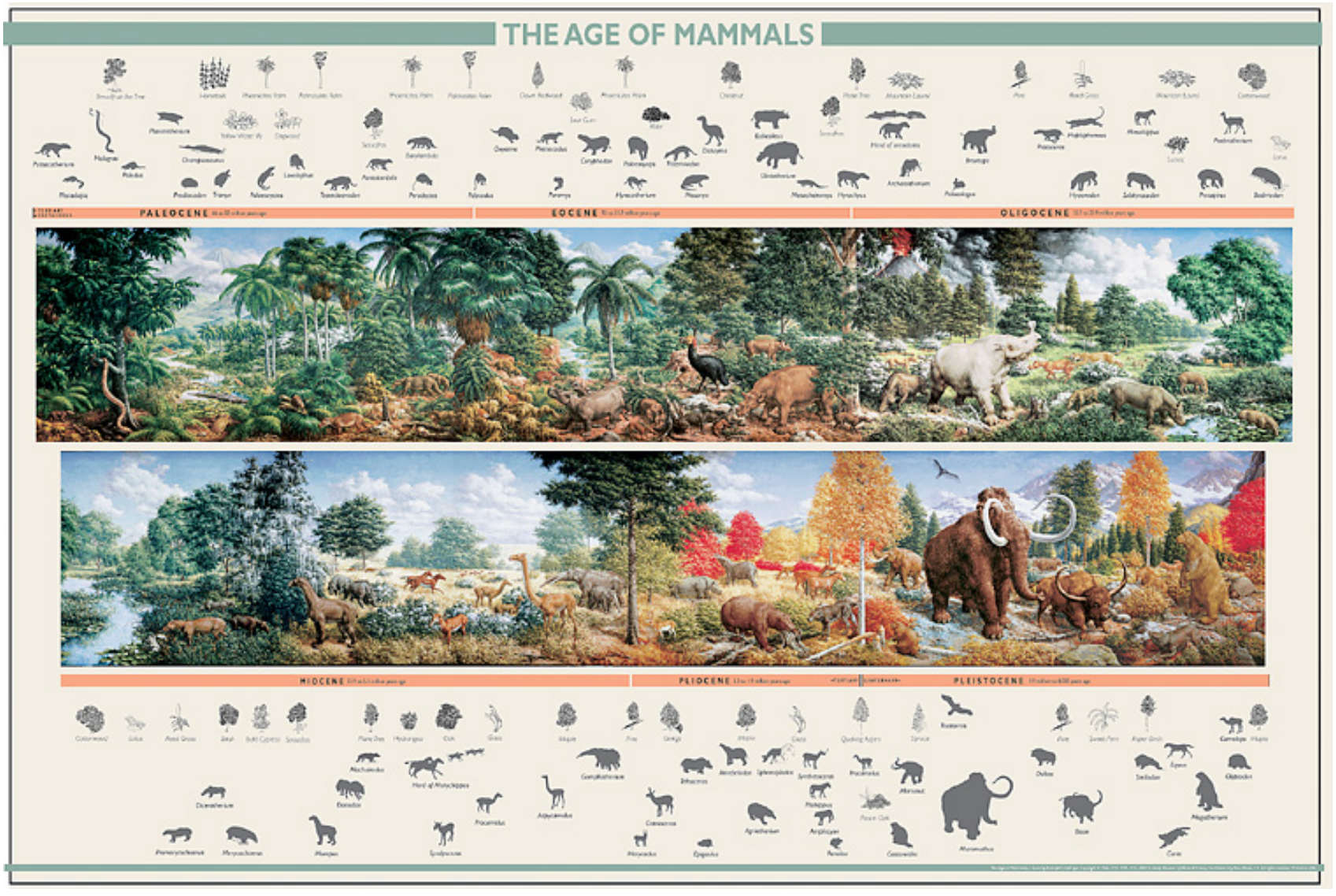
T: survival time
λ: expected number of extinctions per unit time

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

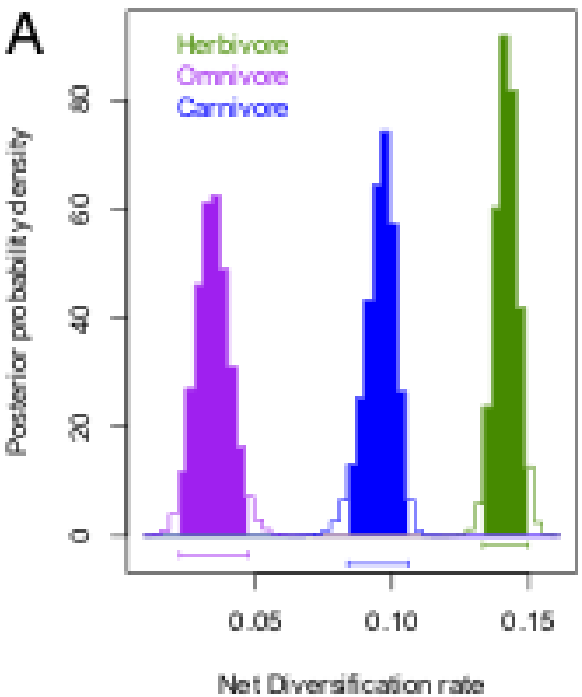


(Yale Peabody Museum)

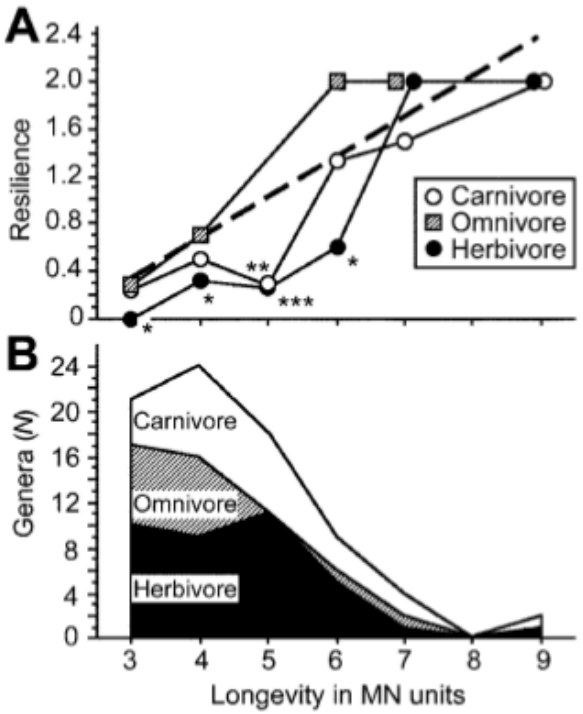
Diet

carnivore, herbivore, omnivore, insectivore

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

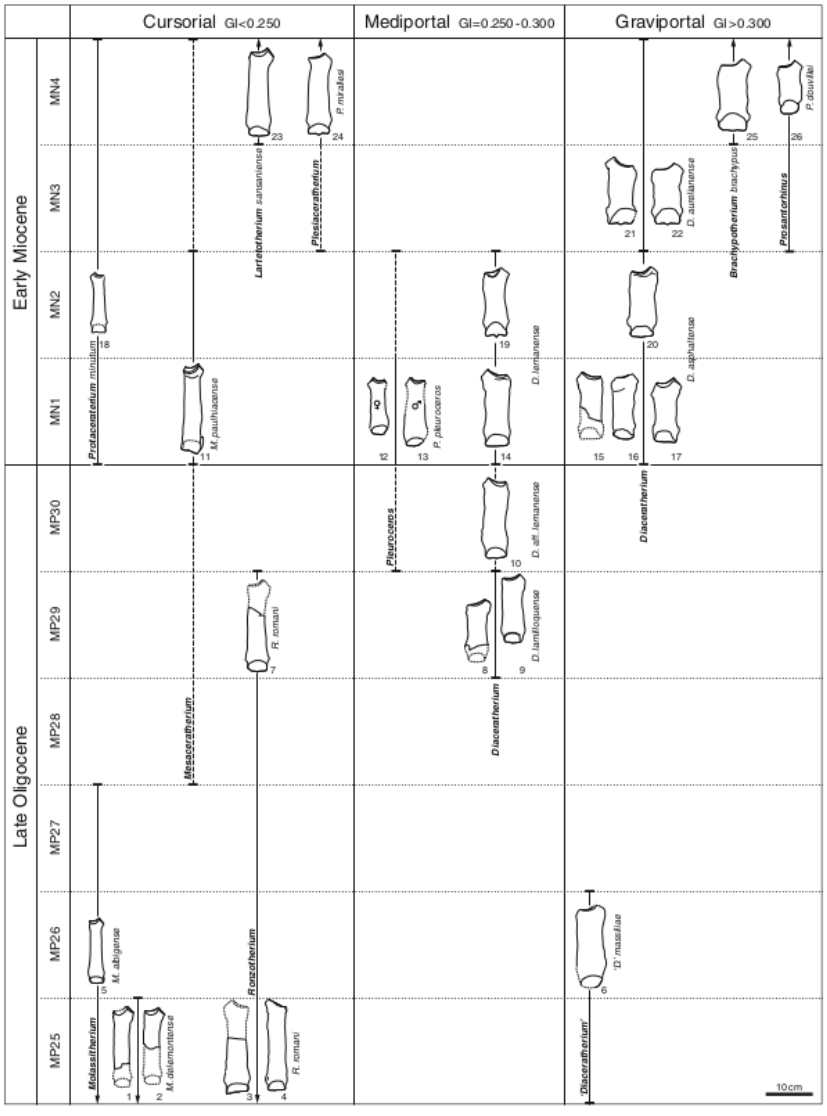


(Price et al. 2012 *PNAS*)



(Jernvall and Fortelius 2004 *Am. Nat.*)

Locomotion

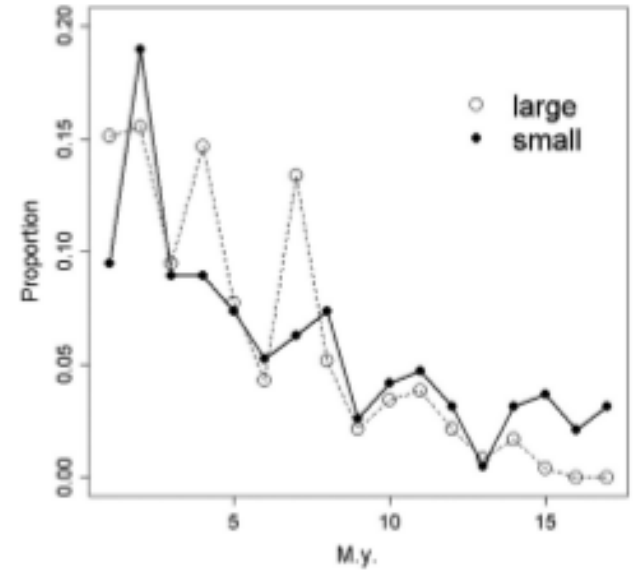


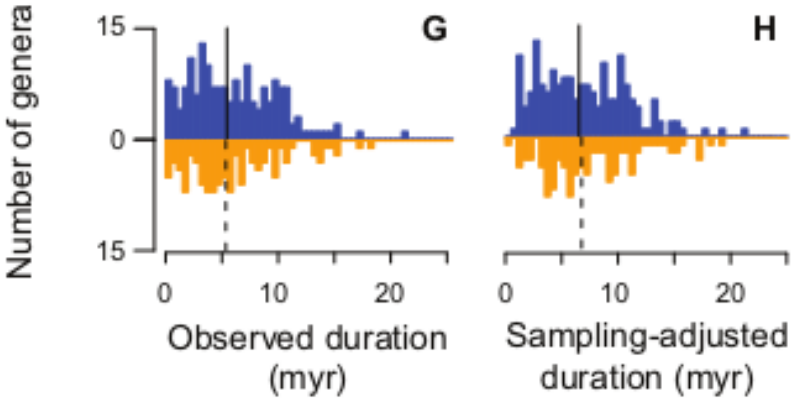
(Scherler et al. 2013 *Swiss J. Geosci.*)

ground dwelling $>$ arboreal

scansorial $\simeq$ ground dwelling

Body size





↑ mass, ↑ range size, ↑ survival

OR

↑ mass, ↓ reproductive rate, ↓ survival

OR

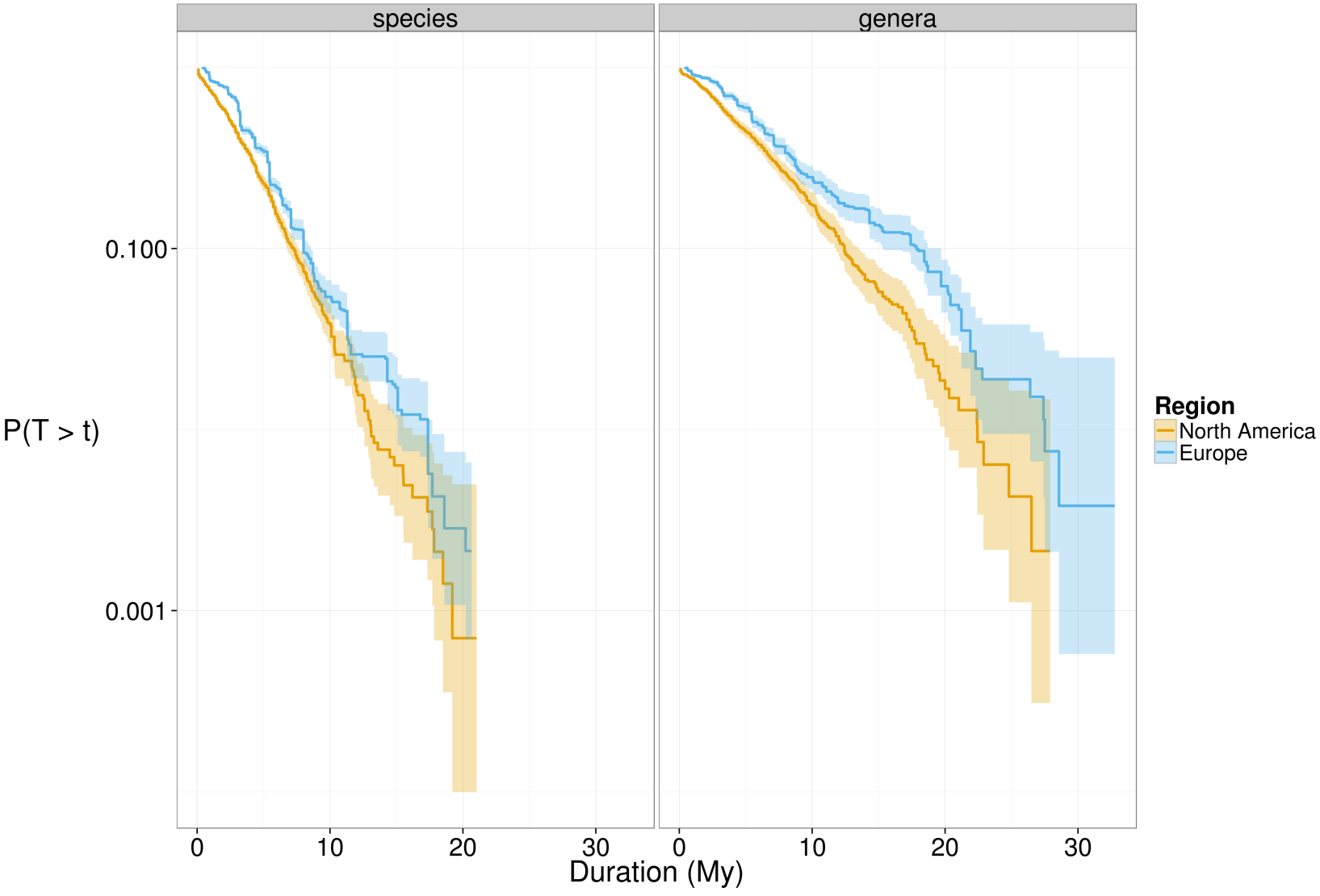
no effect

Regions

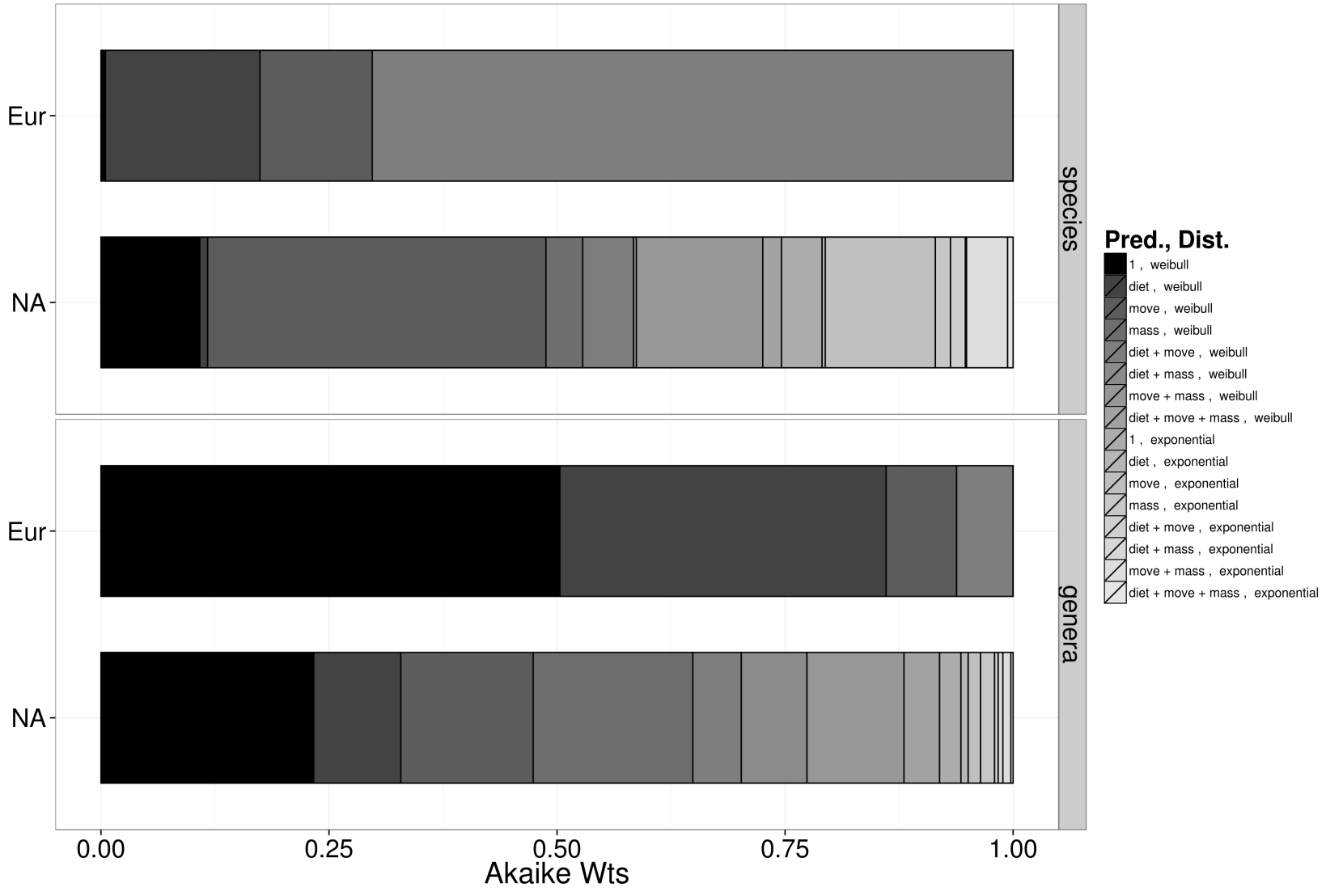
North America:
1805 species, 835 genera
diet, locomotor, mass

Europe:
1727 species, 658 genera
diet, locomotor

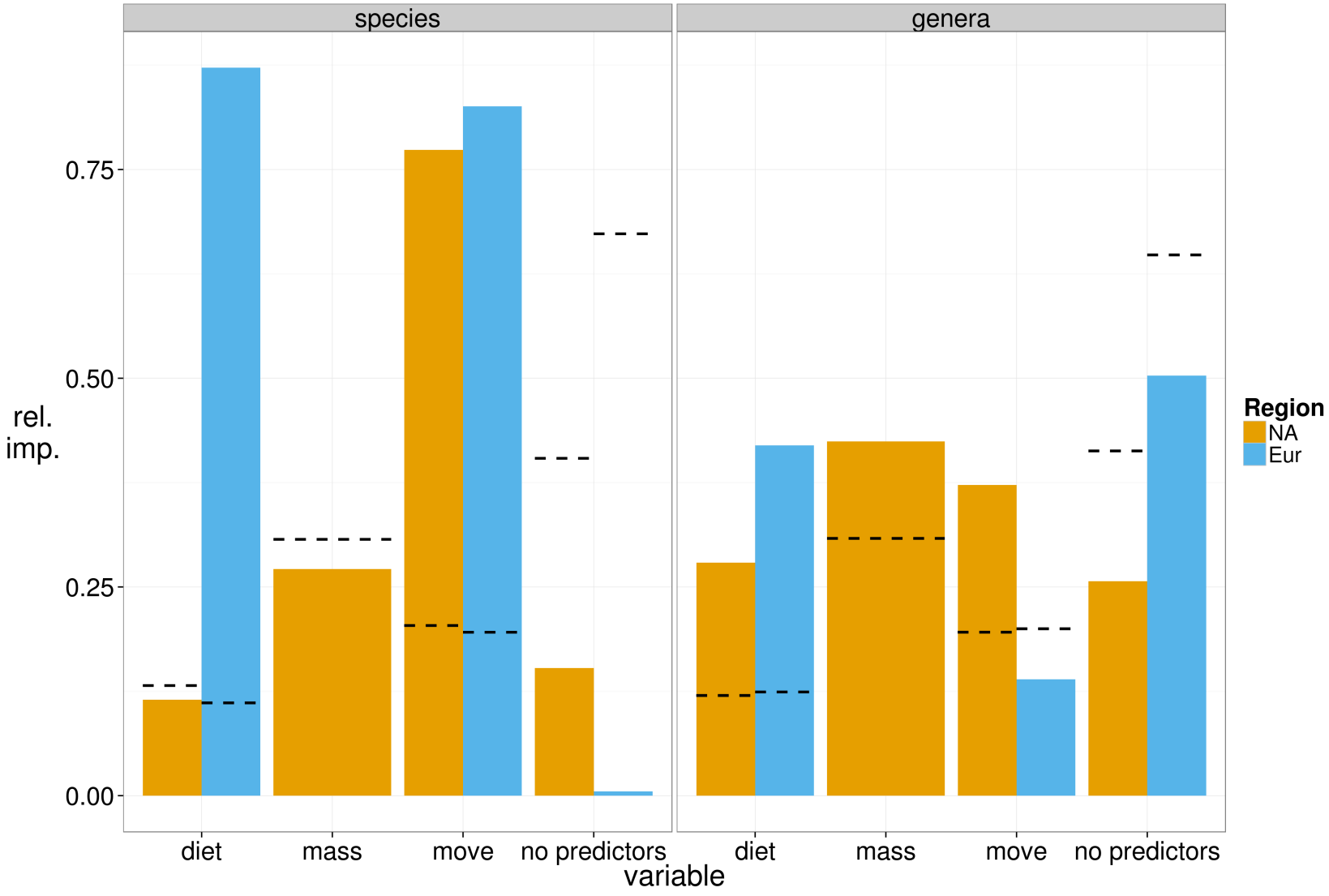
NP regional survival curves



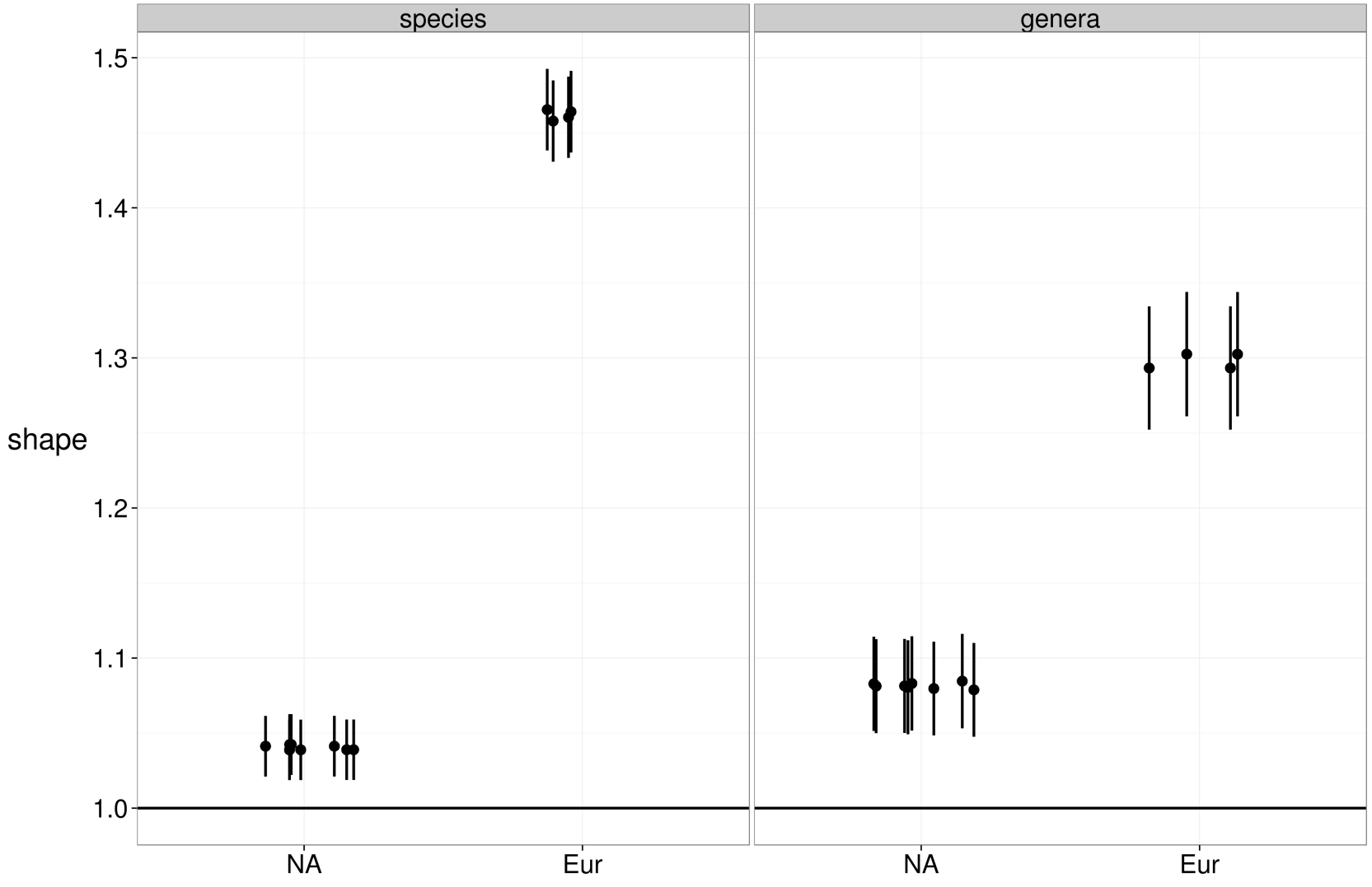
Model selection



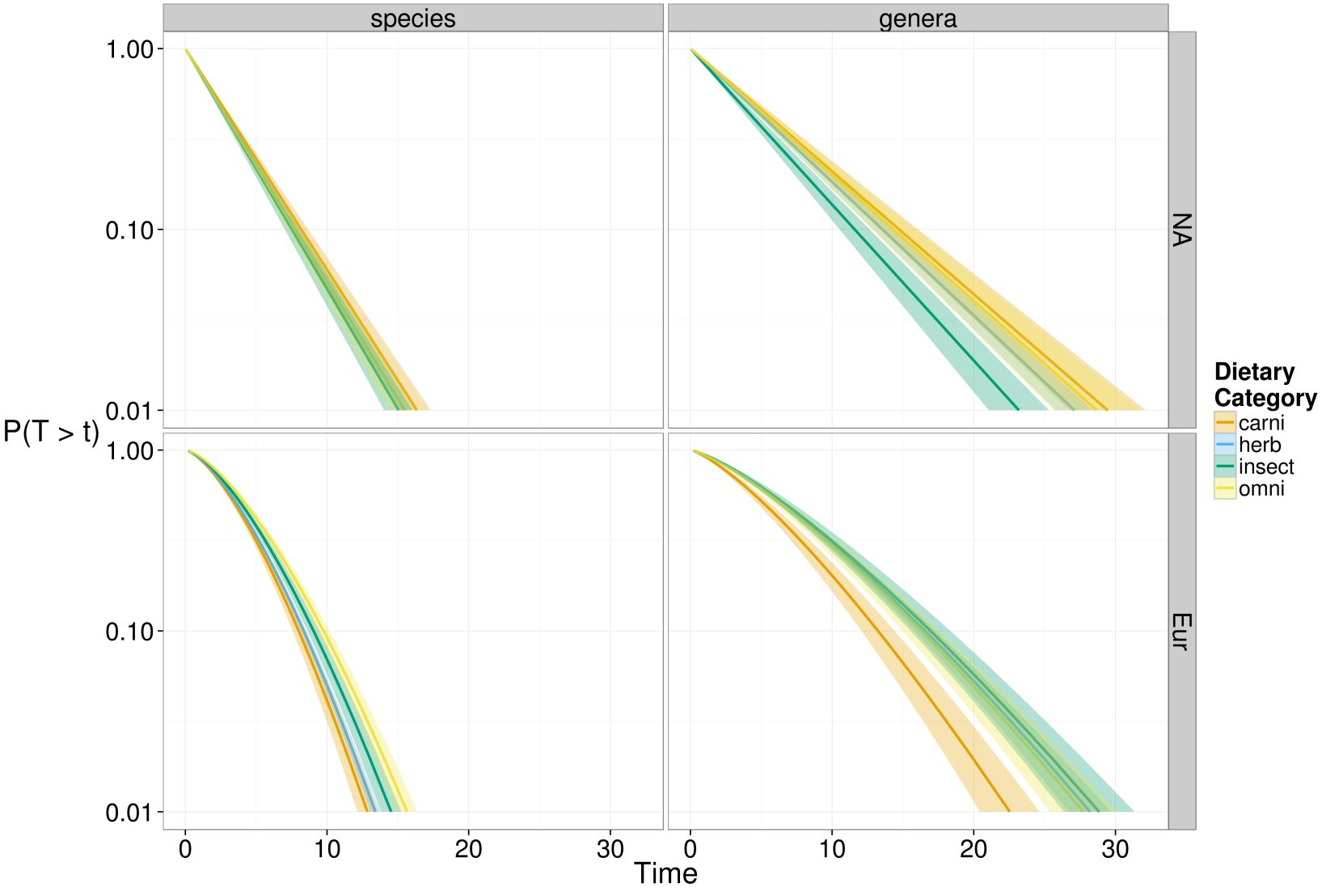
Variable importance



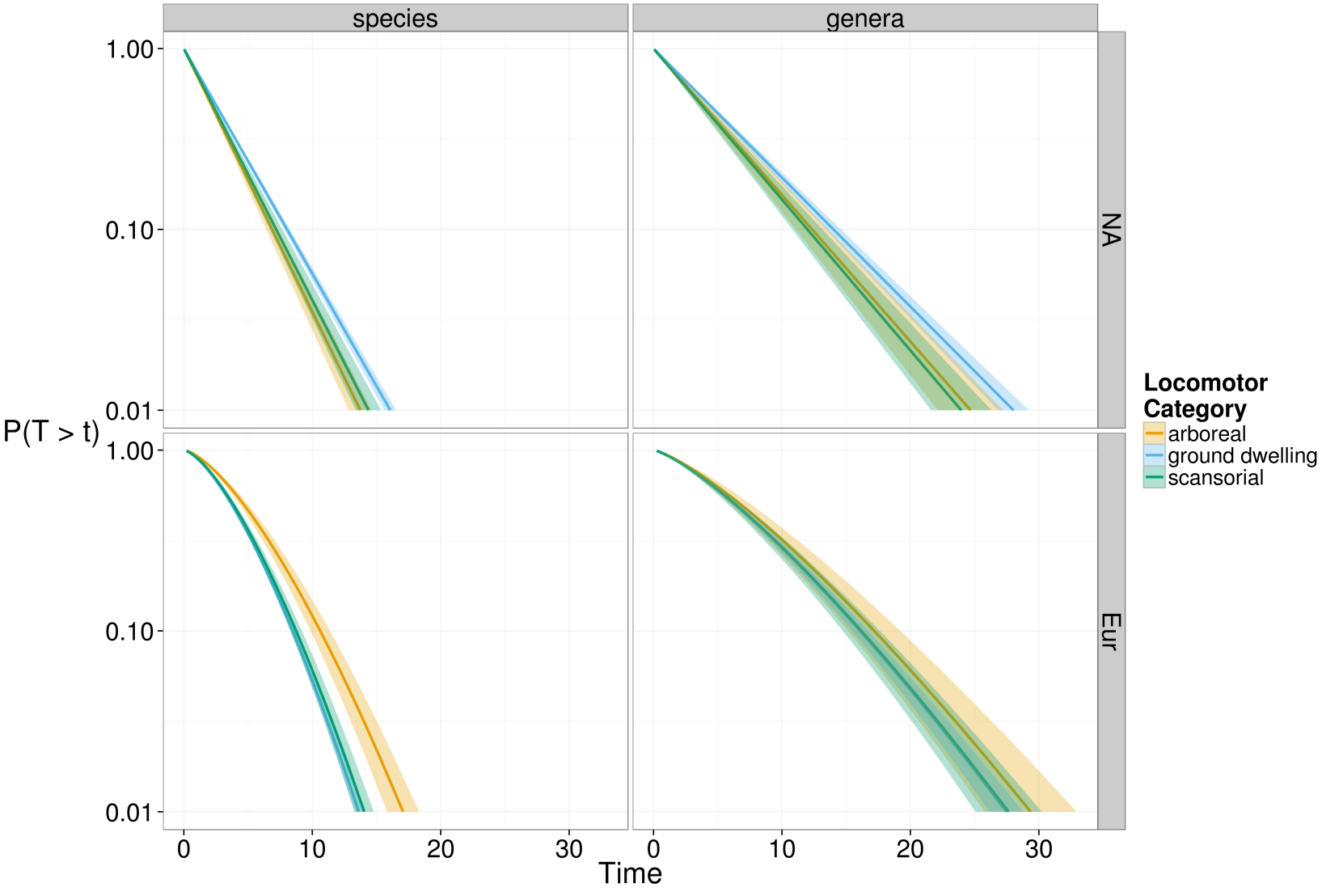
Time dependence



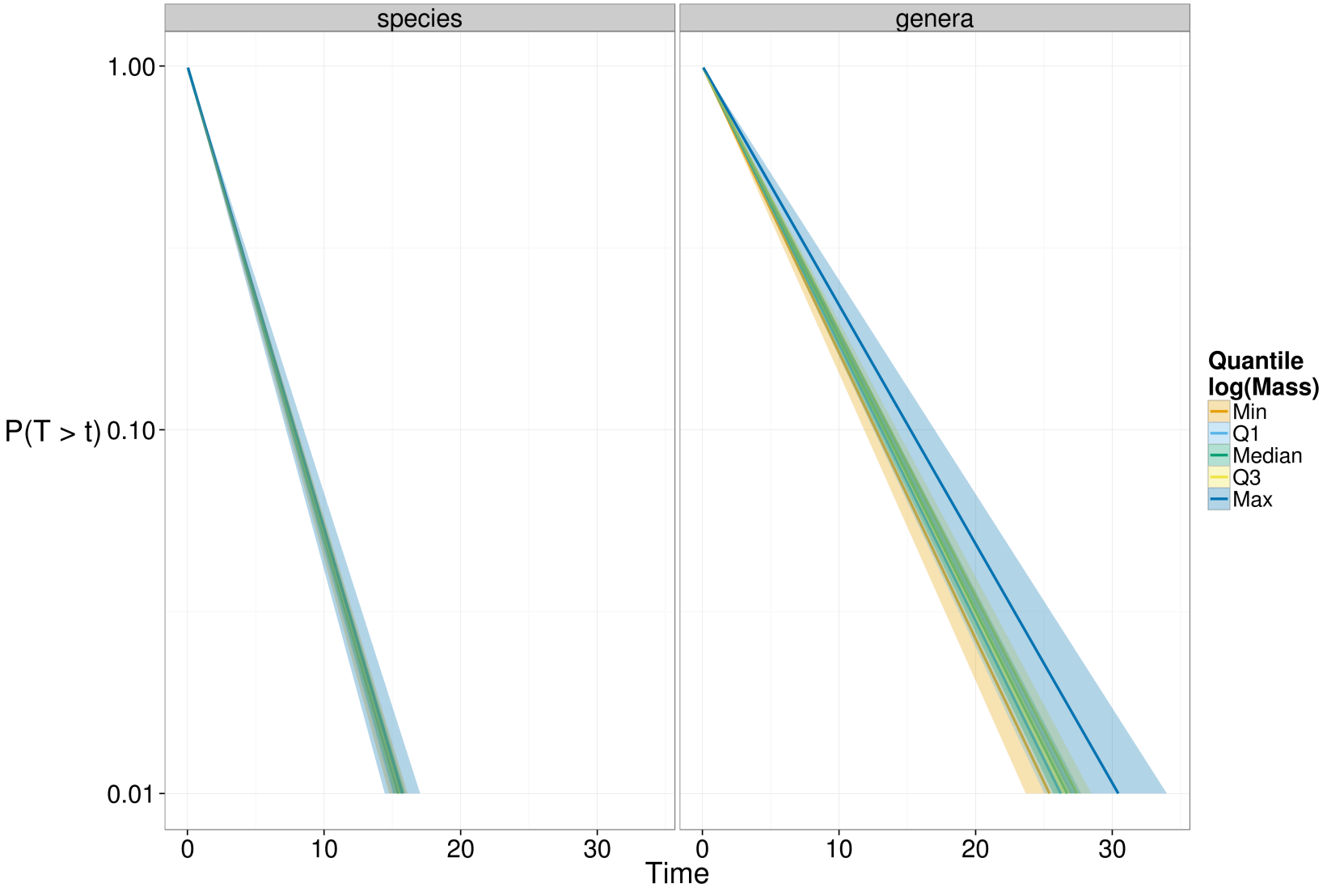
Effect of diet



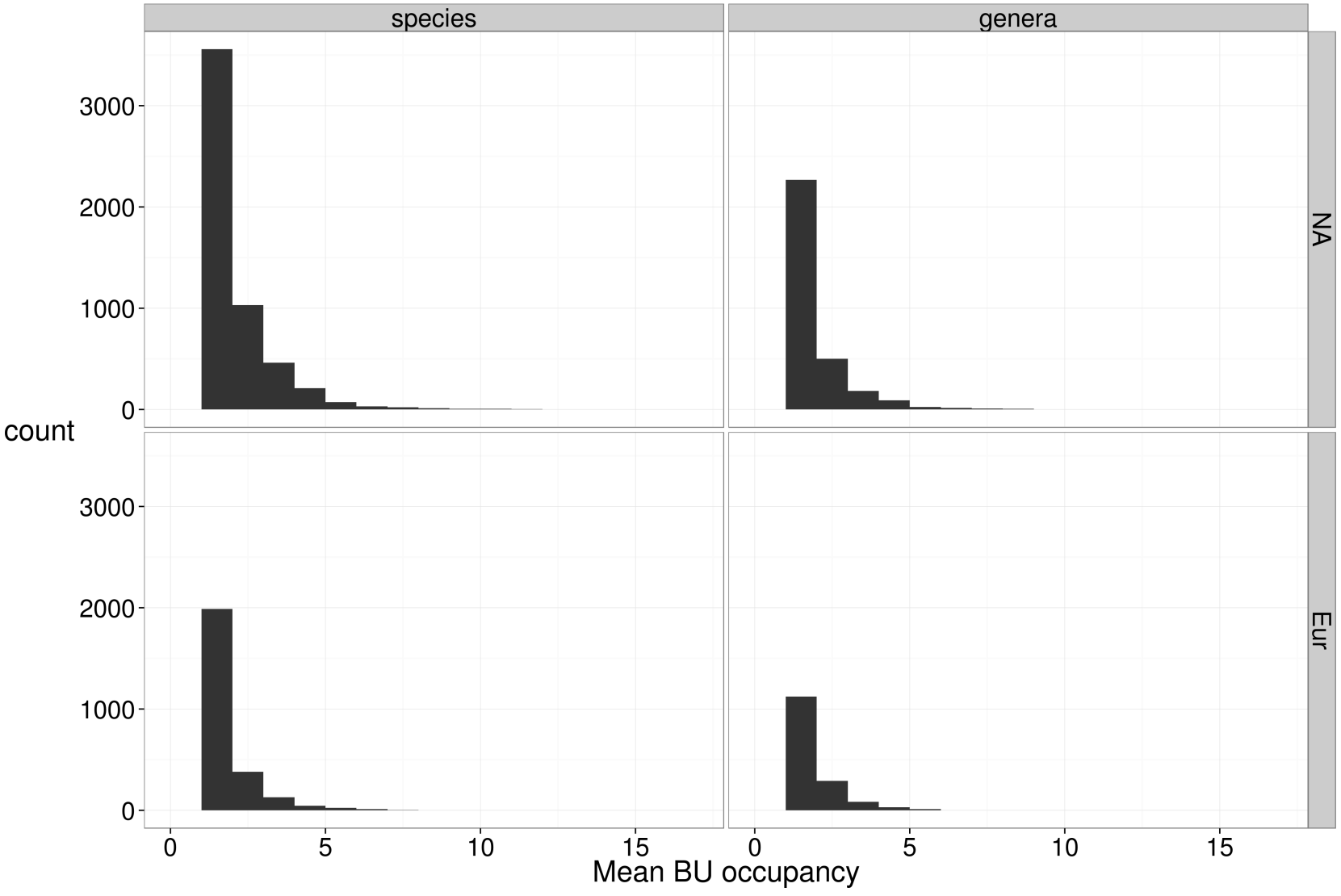
Effect of locomotion



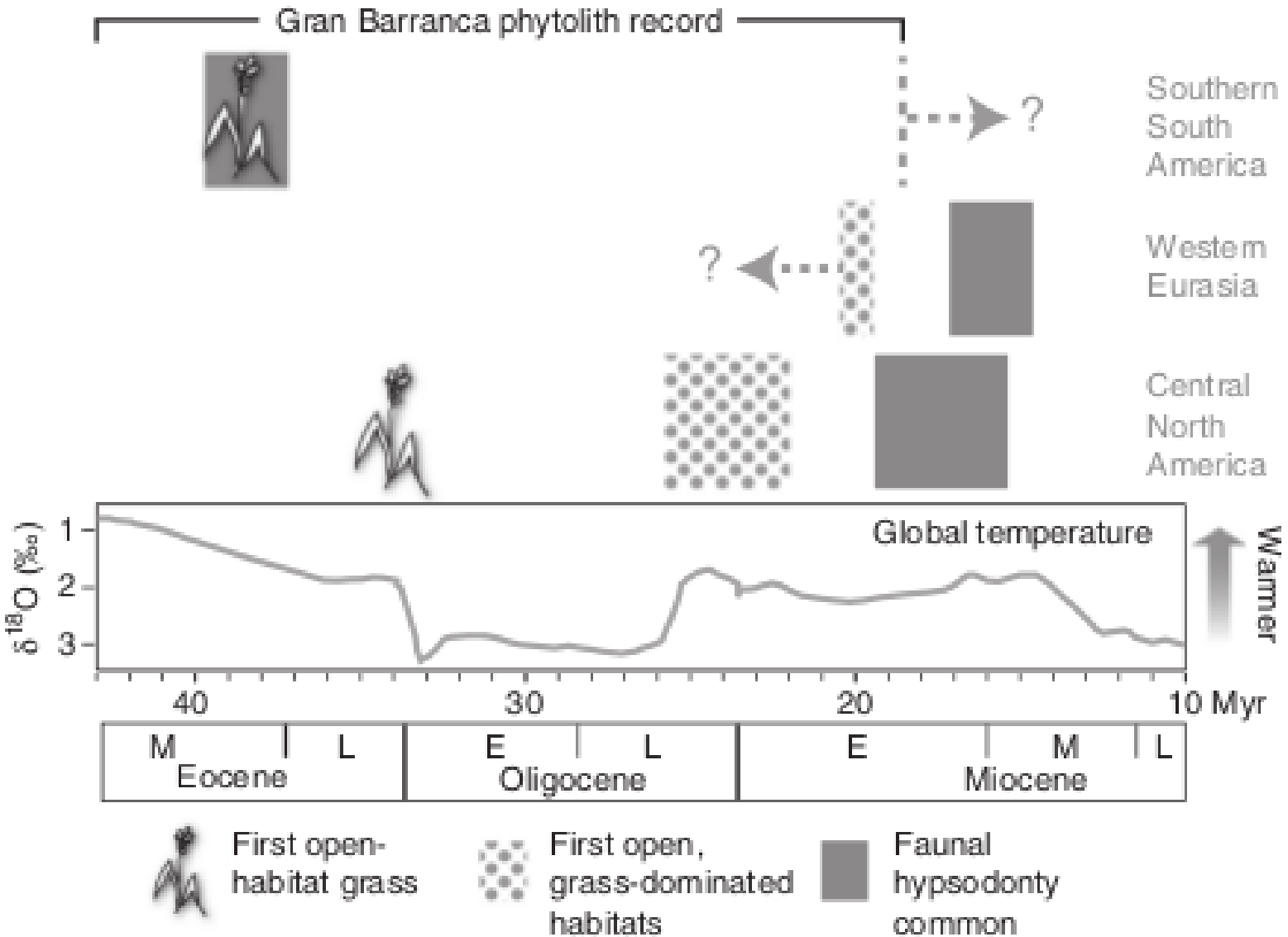
Effect of mass (NA only)



The Elephant in the Range



Climate



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

Laundry list of model improvements

- currently $\hat{k} = c$, future $\hat{k} \propto$ CV climate and/or occupancy
- emergent 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