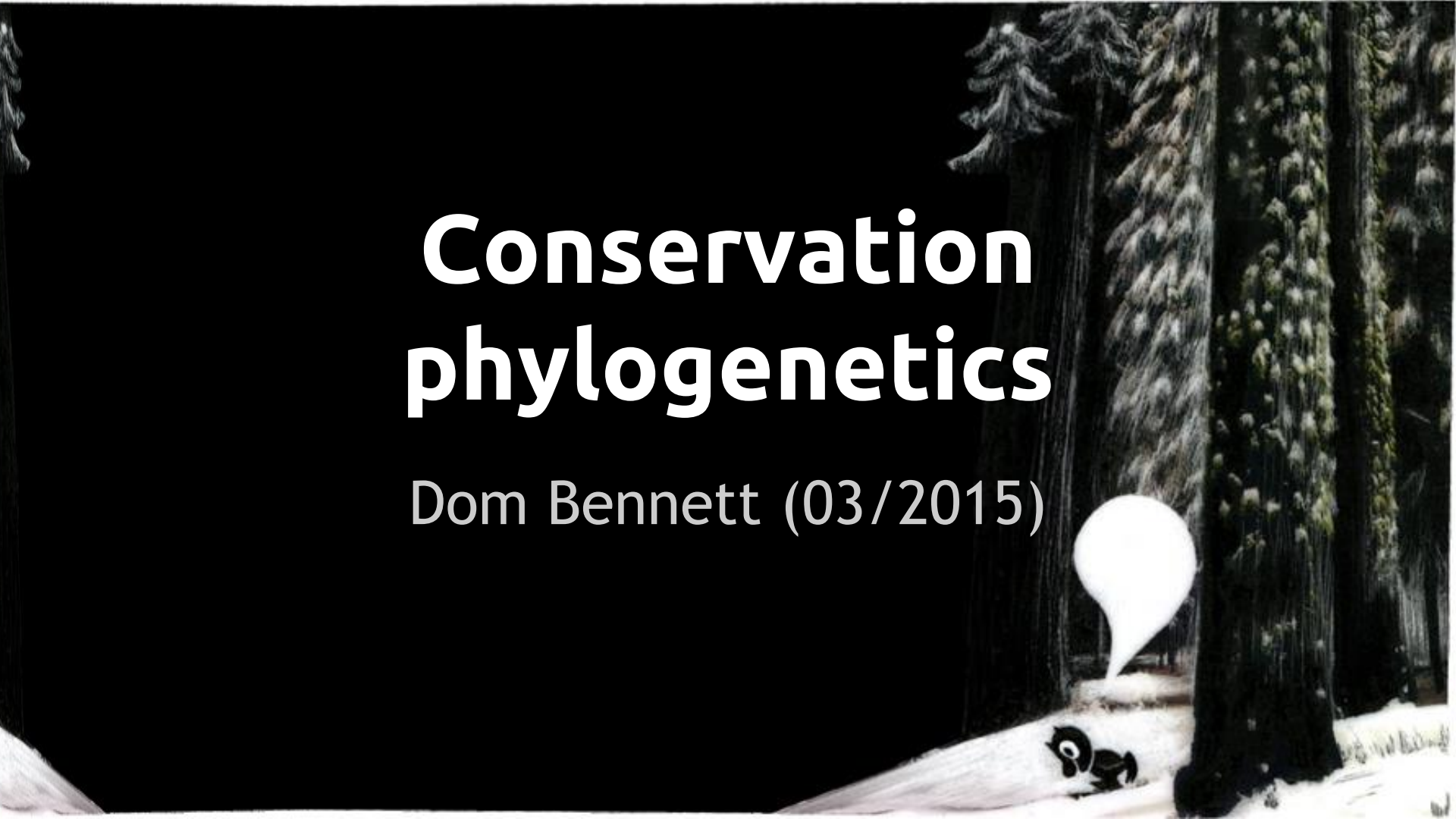
Conservation phylogenetics

Dom Bennett (03/2015)



Objectives

- *Understand* the role phylogenetic diversity can play in conservation
- *Be aware* of a range of phylogenetic metrics
- *Understand* how common metrics work
- *Understand* the current status of its implementation and the caveats of its use
- *Be aware* of the other roles phylogeny can play in conservation

What is biodiversity?

Sample A.

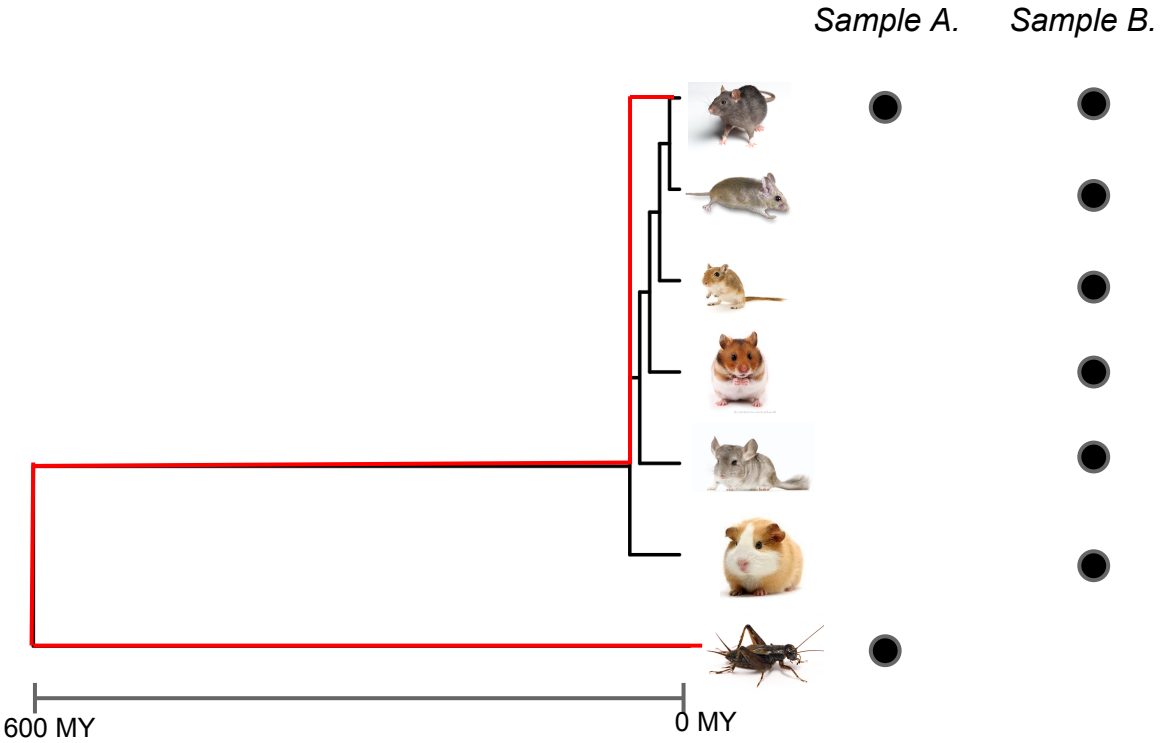
Sample B.

Which of these samples is more biodiverse?

By ‘traditional’ metrics sample A. has fewer species, less total abundance and less evenness than B.

Ref: Purvis & Hector 2000 *Nature* 405, 212-219

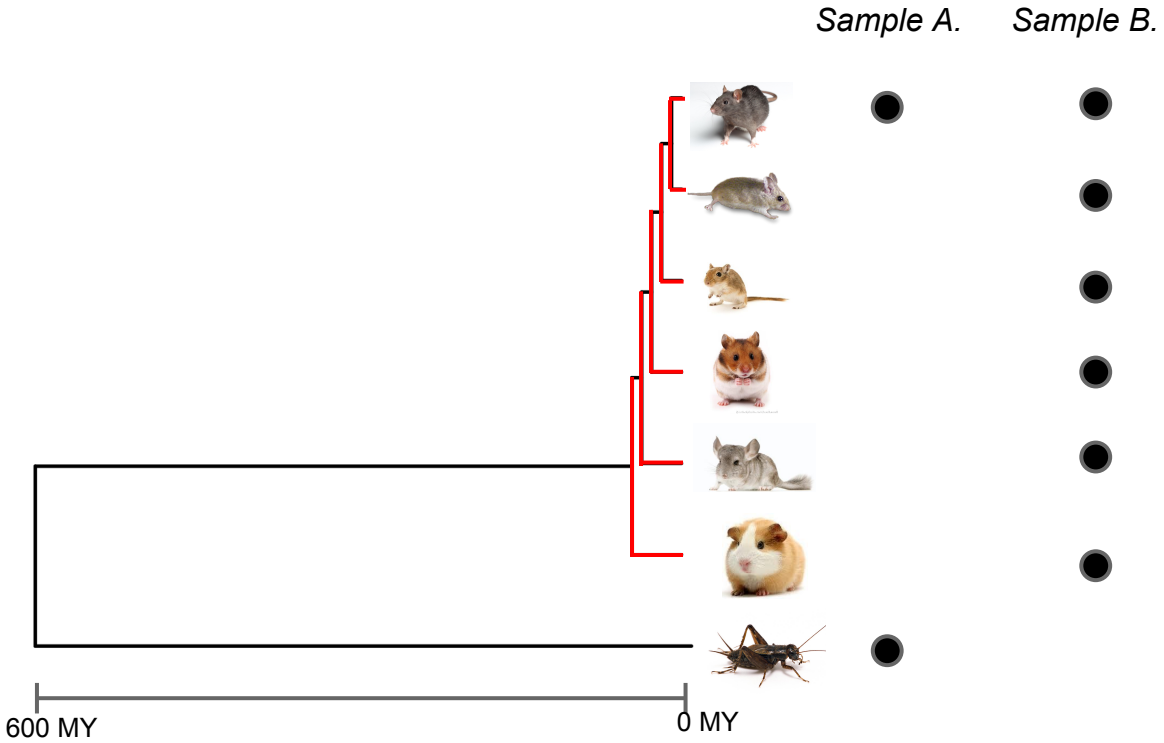
What is biodiversity?



But in terms of phylogenetic diversity, sample A. is greater.

Sample A, PD = ~10,000s MY

What is biodiversity?



But in terms of phylogenetic diversity, sample A. is greater.

Sample A, PD = ~10,000s MY

Sample B, PD = ~100s MY

The phylogeny offers an alternative, and arguably better, measure of biodiversity that can be calculated in years.

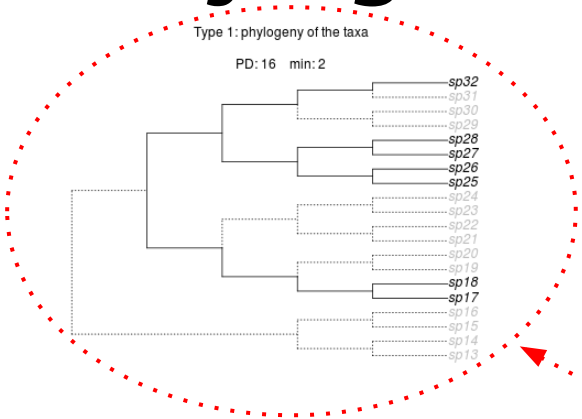
Metrics aside 1

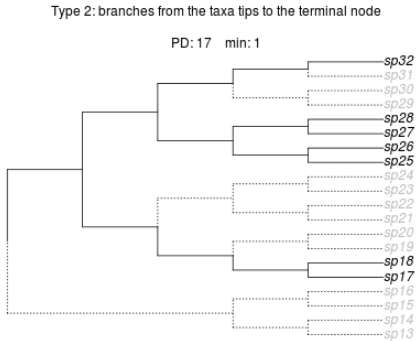
Measuring phylogenetic diversity

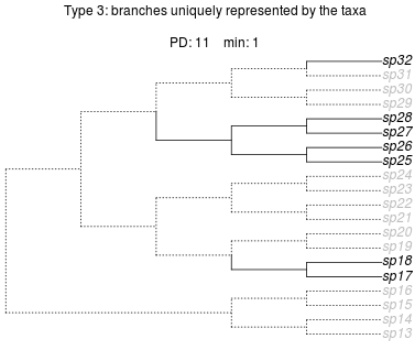
Many measures

- What do we mean by phylogenetic diversity?
- A range of metrics exist:
  - Phylogenetic Diversity (PD)
  - Phylogenetic Species Variability (PSV)
  - Mean Phylogenetic Distance (MPD)
  - Net Relatedness Index (NRI)
  - Nearest Taxon Index (NTI)

Phylogenetic Diversity (PD)





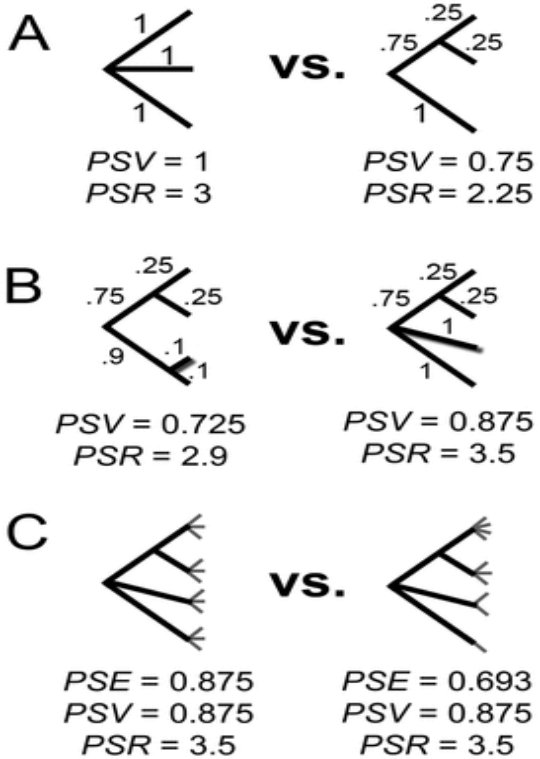


Dan Faith's Phylogenetic Diversity: the total branch length of the phylogenetic tree represented by the species in a community.

Not independent of species richness. Doesn't scale linearly.

Ref: Faith 1992 Conservation evaluation and phylogenetic diversity. *Biological Conservation*

Helmus' Phylogenetic Measures



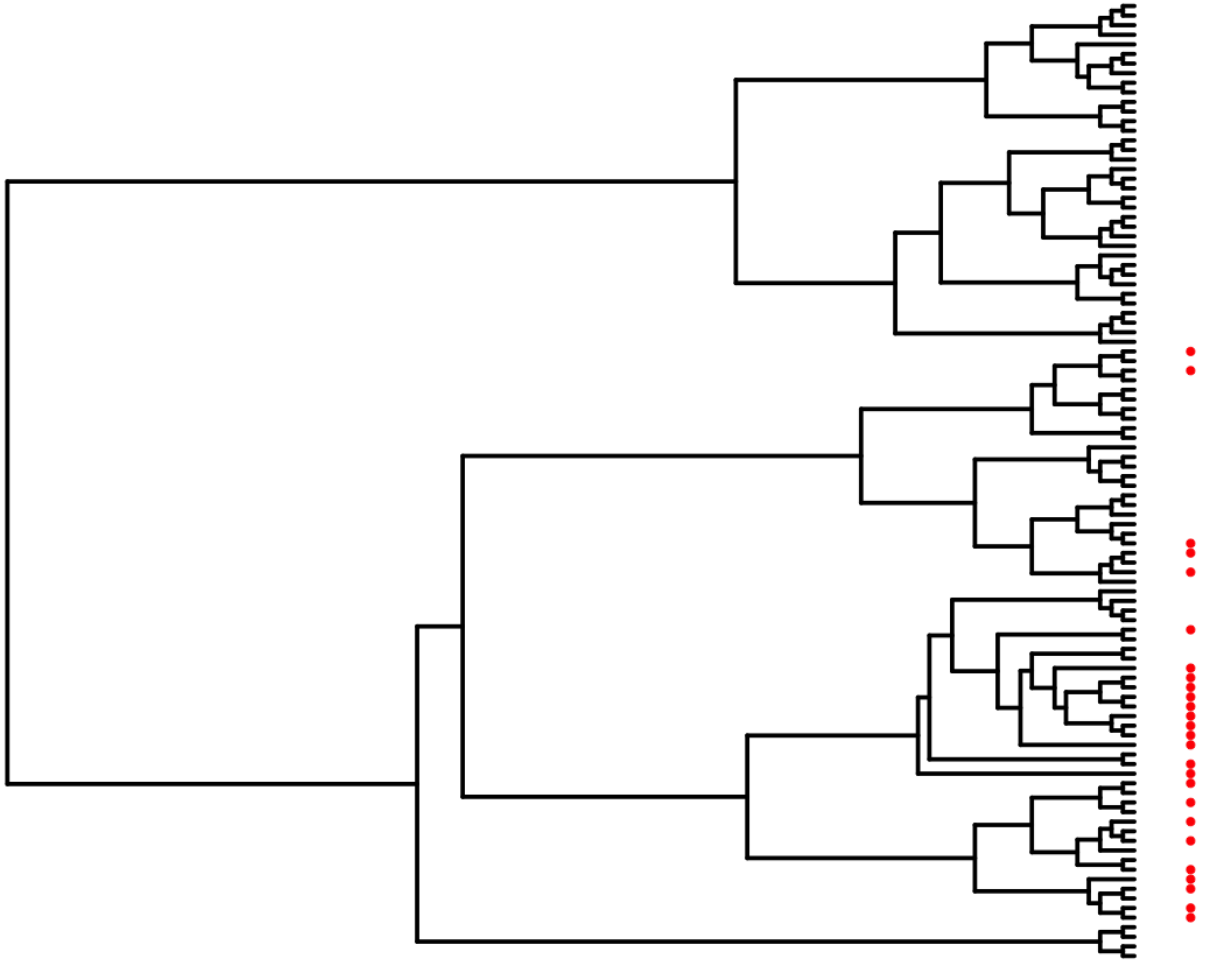
Phylogenetic Species Variability (PSV) is a measure of the variability in phylogenetic shape.

- Independent of species richness
- Scales linearly
- Not measured in years, 0-1
- PSV == 1, all species are equally unrelated
- PSV -> 0, as species become more related

Ref: Helmus et al. 2007 Phylogenetic Measures of Biodiversity. Am. Nat.

The shrinking tree of life

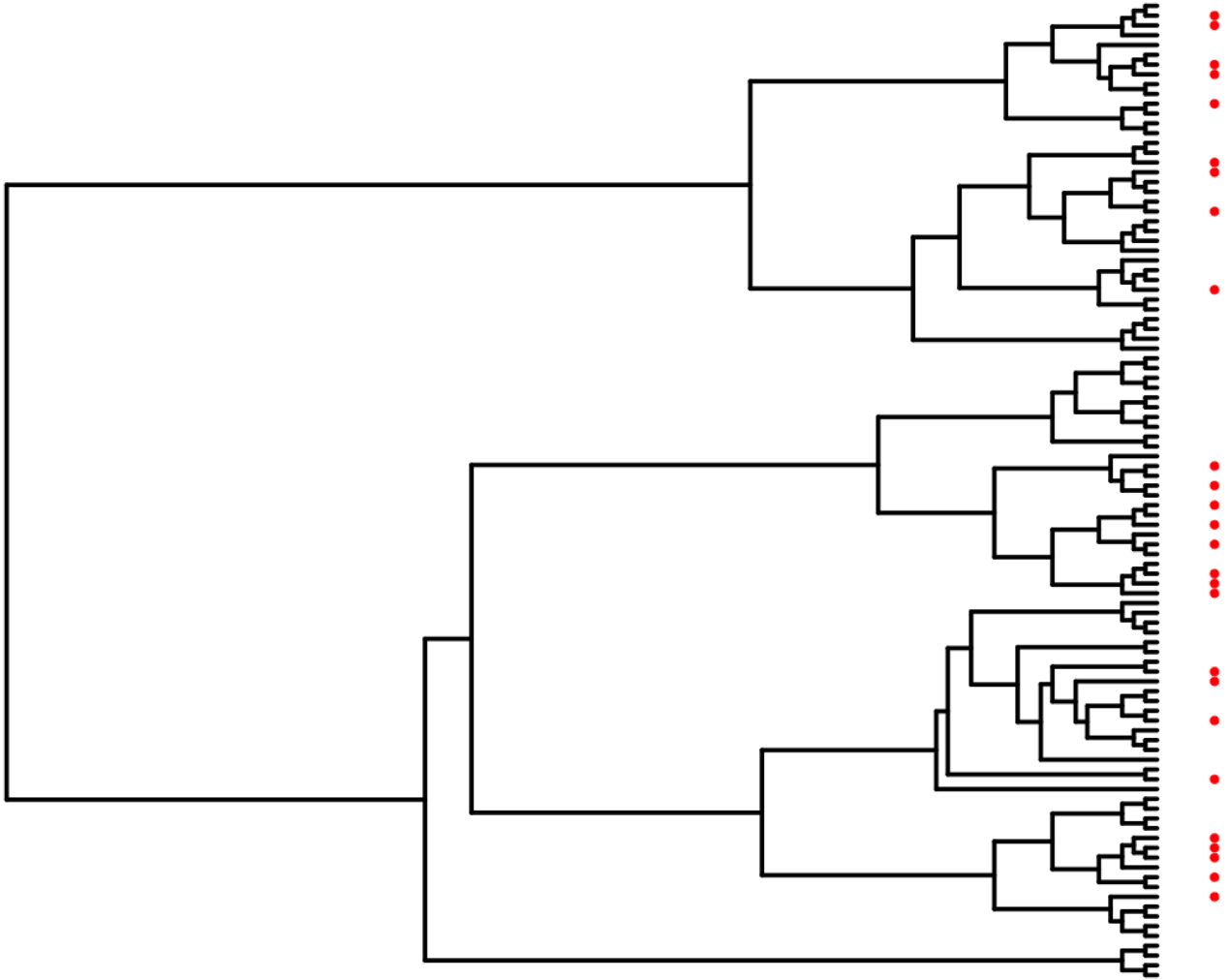
- First question: *how is phylogenetic diversity doing on a global scale?*
- To answer this we can perform a permutation test



Each dot represents a species at risk of extinction.

If these species were lost, we would stand to lose **82 MY** of evolutionary history.

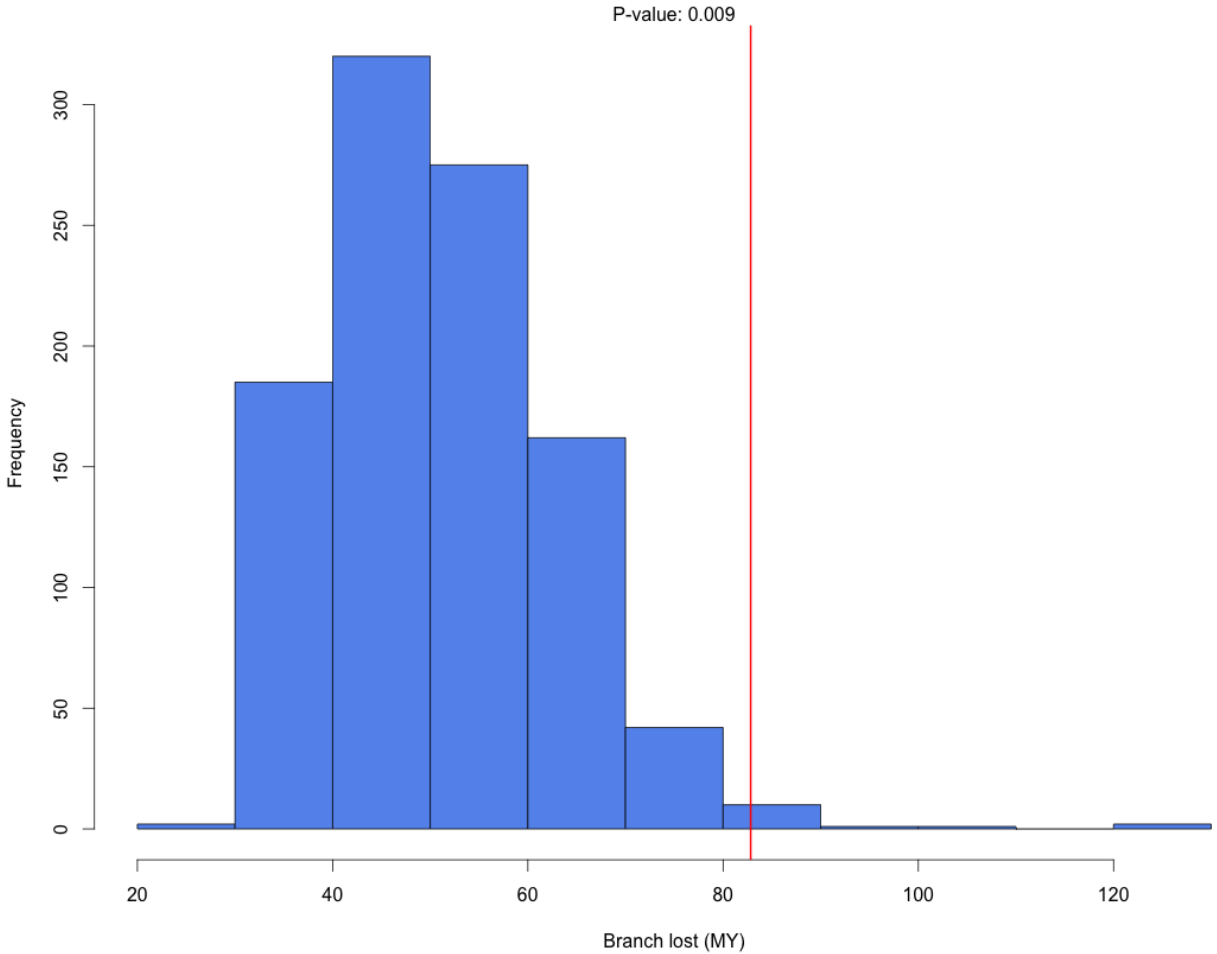
How much would we stand to lose for a random subset of species?



For this random subset, we only stand to lose **45 MY**.

If we create multiple random subsets, calculate the loss we can generate a null distribution of branch loss when there is *no phylogenetic signal*.

…. this is the **permutation test**.



In this example, the vast majority of random subsets of species leads to a much lower loss in branch length.

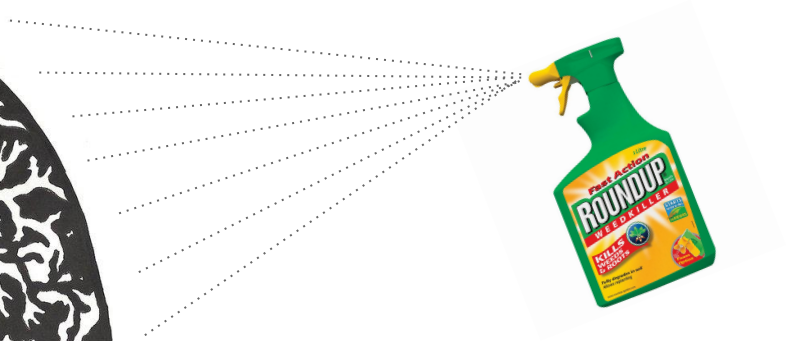
This is just fake data.

But many have found this it to be true using IUCN Red List categories as proxies for extinction risk for:

- birds
- mammals
- other groups

Ref: Bennett, P. M. & Owens, I. P. F. 1997 Variation in extinction risk among birds: chance or evolutionary predisposition? Proc. R. Soc. Lond. B 264, 401-408.

The tree of life *is* shrinking



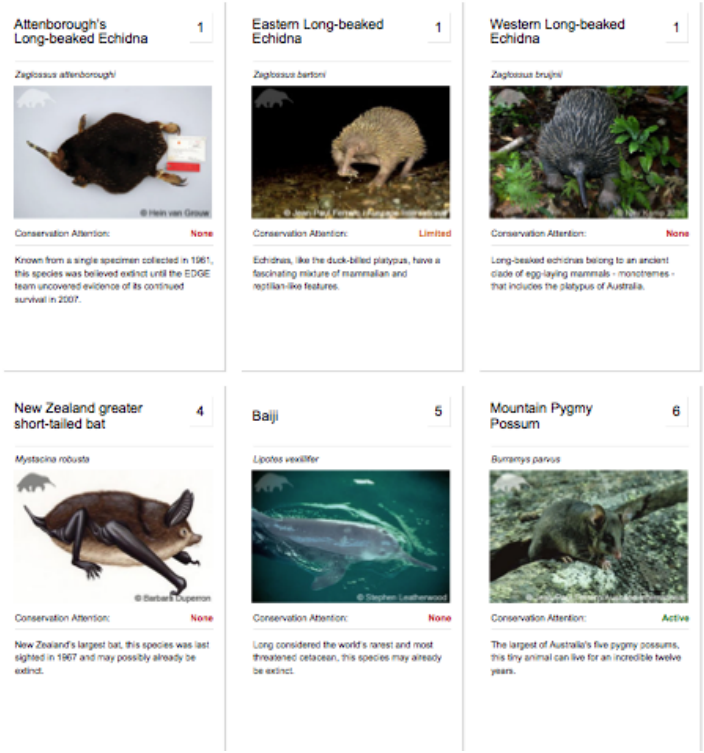
…. what to do about it?

How best to conserve the tree?

EDGE

Use this equation to combine measure of Evolutionary Distinctness (ED) and Global Endangeredness (GE) to create a ranked list of species most important to conserve.

$$EDGE = \ln(1 + ED) + GE * \ln(2)$$



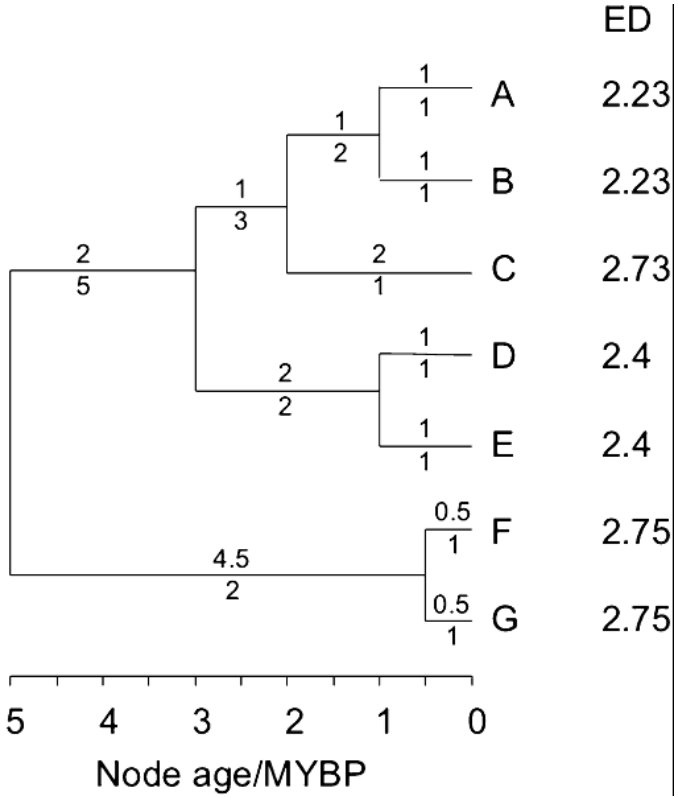
Metrics aside 2

Measuring evolutionary distinctness

Three main measures

- Pendant Edges (PE)
  - The length of the branch that connects the tip to the tree
- Equal Splits (ES)
  - The sum of branch lengths connecting the tip to the root, with branch lengths divided by two at every split
- Fair Proportion (FP)

Fair Proportion



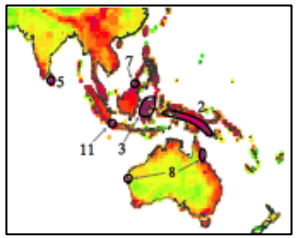
The sum of the length of branches that connect a tip to the root, with each branch length divided by the number of descendants.

Ref: Isaac et al. 2007. Mammals on the EDGE: Conservation Priorities Based on Threat and Phylogeny. PLoS ONE

Contested methods ….

Is saving the most ED, the best option for averting the shrinking tree?

- Phylogenetic Endemism (PE) -- identify *regions* with highest proportions of ED species
- After Downlisting a species gives the Expected Phylogenetic Diversity (ADEPD) -- an economic metric that uses cost-benefit to save as much PD



common name	scientific name	EPD gain (Myr)	EPD gain per cost unit (Myr/ $MM)	IUCN	ADEPD score	required expenditure (US$)	current expenditure (US$)
Botha's lark	*Spizocorys fringillaris*			EN	1.185	71000	0
tooth-billed pigeon	*Didunculus strigirostris*			EN	9.225	695000	209000

Refs:
Rosauer & Jetz 2015 Phylogenetic endemism in terrestrial mammals. *Global Ecology and Biogeography*.
Nunes et al. 2015 The price of conserving avian phylogenetic diversity: a global prioritization approach. *Phil. Trans. R. Soc.*

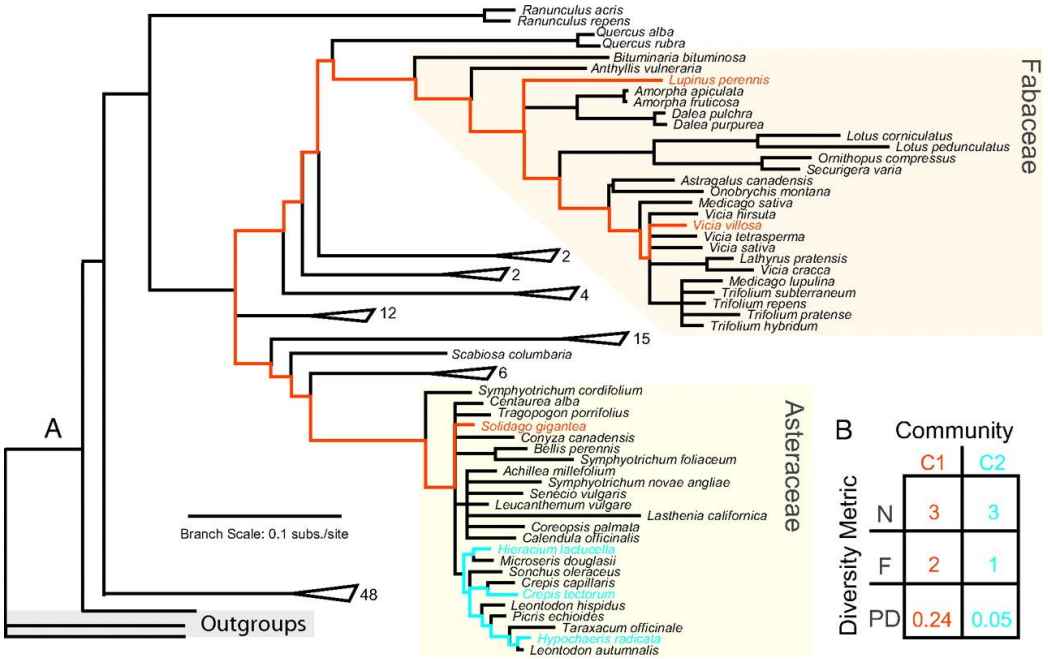
Why care? *Evolutionary information*

- Biodiversity is information.
- By preserving life's information we're safe-guarding the ability of human and nonhuman life to persist.
- Phylogenetic diversity offers a good metric that can incorporate number of independently evolving lineages and the different lifestyles, and hence, information they each contain.

Ref: Steffen et al. 2015 Planetary boundaries: Guiding human development on a changing planet. Science.

Why care? *Functional diversity*

- From the start it has been suggested that PD can be used as a proxy for functional diversity.
- Evidence is mixed. Where functional diversity is difficult to get, it may play an important role.
- Functional diversity is often then linked to ecosystem functions and services.
    - Great extrinsic value argument

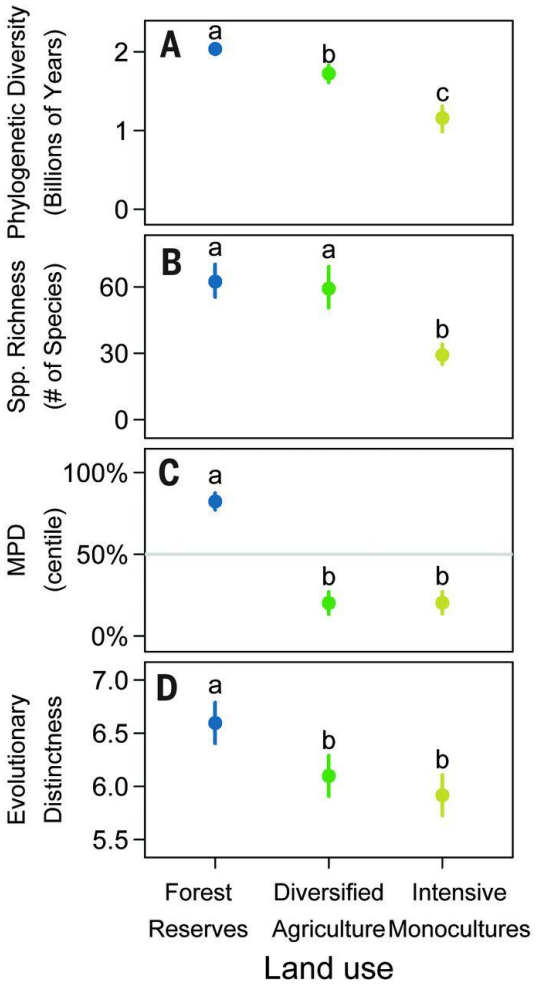


Hypothetical communities and their relative biodiversity values for different metrics. From Cadotte et al. (2008) who show that PD can significantly explain variations in plant productivity.

Ref: Cadotte et al. 2008 Evolutionary history and the effect of biodiversity on plant productivity. PNAS.

Local scale

- We’ve considered things on a global scale, these reasons for conserving the tree act at the local scale.
- Few have explored how local levels of phylogenetic diversity are responding to human impact.



Ref. Frishkoff, L.O. et al., 2014. Loss of avian phylogenetic diversity in neotropical systems. Science, 1343.

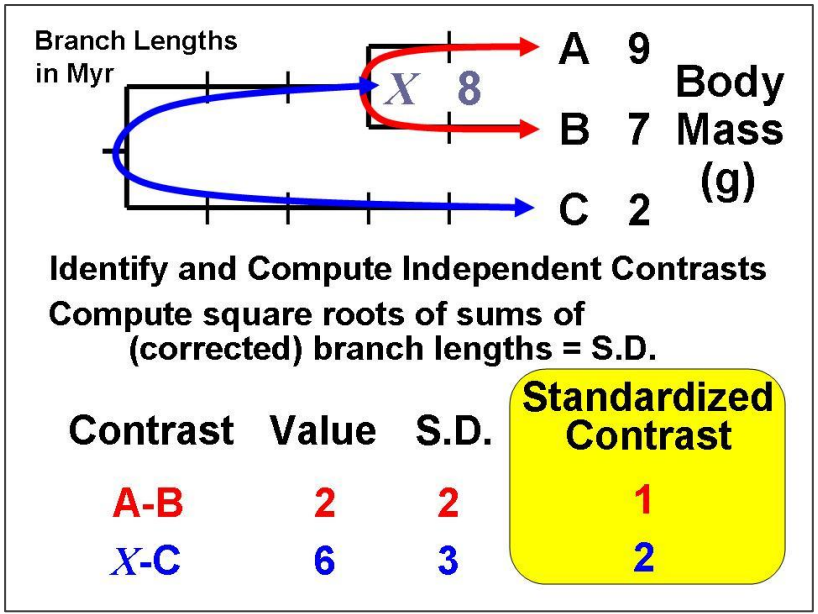
Why care? *Intrinsic value*

- Attenborough's Echidna probably has no practical value (functionally, evolutionary information)
- But it should be conserved as it represents a unique part of evolutionary history
- This is the 'Ming vase argument'

Ref: Rosauer & Moers 2013 Nurturing the use of evolutionary diversity in nature conservation. *TREE*.

Towards a predictive conservation

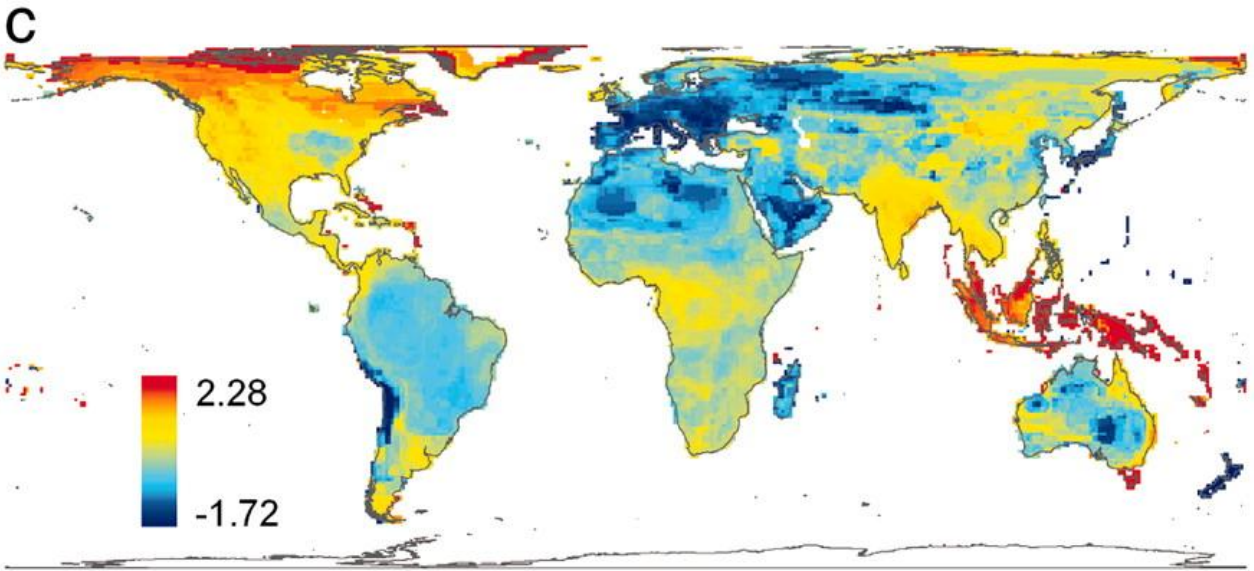
- So far, only considered how the phylogeny can be used to measure loss
- But the phylogeny can be used to make predictions
- PICs can be used to identify traits correlated with extinction risk
- *What types of species are likely to go extinct?*



en.wikipedia.org/wiki/Phylogenetic_comparative_methods#mediaviewer/File:Phylogenetically_Independent_Contrasts_1.jpg

Latent risk in mammals

- Create a model of how traits relate to extinction risk (usually using Red List Categories)
- Use residuals to identify species with higher or lower risk of extinction than expected -- latent risk.
- Extinction risk is greater for large bodied mammals.
- Protect large bodied mammals?

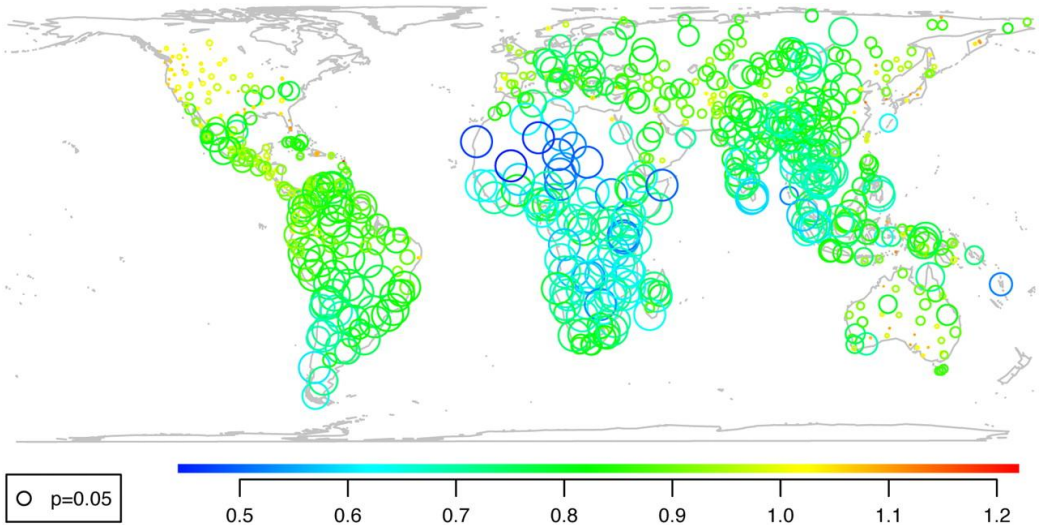


Red → high latent extinction risk.
Blue → low latent extinction risk.

Ref. Cardillo et al. (2006) Latent extinction risk and the future battlegrounds of mammal conservation. PNAS

Local scale, again!

- Threat intensity is not even across regions; a global analysis ignores
- For mammals, extinction risk is still non-random at regional levels
- To deliver more information on latent extinction risk, models must be conducted at local scales
- Requires more data!

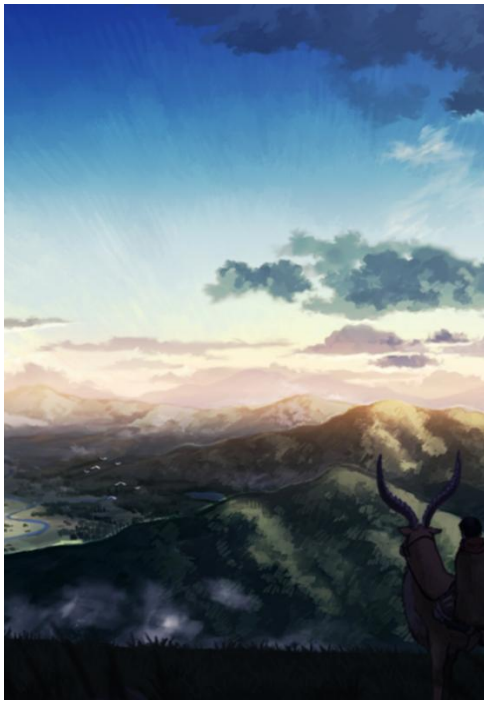


Non-random loss of species in WWF regions. Values of 1, indicate random loss. Values lower indicate clumping. Size of circles indicate significance.

Ref. Davies, T.J. et al. 2008 Phylogenetic trees and the future of mammalian biodiversity. PNAS 105 (Suppl.), 11556-11563.

Conclusions

- Phylogeny can potentially play an important role in conservation
  - New metrics of biodiversity, and proxies
  - Towards prediction with the use of comparative models
- But we’re still not sure how to use it
  - *Data deficiency*: DNA data, constructing a tree of life, ecological impact at the local scale
  - *Mathematical*: what metric is best?
  - *Philosophical*: what are we trying to achieve?



Further Reading

- Winter et al. 2013 Phylogenetic diversity and nature conservation: where are we? TREE
  - *Overview of how phylogenetic metrics have been incorporated into conservation.*
- Isaac et al 2007 Mammals on the EDGE: Conservation Priorities Based on Threat and Phylogeny. PLoS ONE
  - *The paper that invents the notion of saving the evolutionary distinct.*
- Davies, T.J. et al. 2008 Phylogenetic trees and the future of mammalian biodiversity. PNAS 105 (Suppl.), 11556-11563.
  - *Outlines a framework for creating a predictive use of the phylogeny in conservation*
- Mouquet et al 2012 Ecophylogenetics: advances and perspectives. Biological reviews of the Cambridge Philosophical Society
  - *Good review of how the phylogeny can be used in ecology, evolution and conservation.*
- Frishkoff et al. 2014 Loss of avian phylogenetic diversity in neotropical agricultural systems. Science.
  - *First attempt to investigate how phylogeny responds to human impact at the local scale*
- *http://rstb.royalsocietypublishing.org/content/370/1662*
  - *Special edition looking at incorporating phylogeny and conservation*