Biogeography and macroevolution of Atlantic Forest anurans

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Hello everyone, thanks for comming. First of all, I'd like to thank Laura for the invitation and for the introduction as well. Well, first when Laura invited me to give this talk I first thought I could maybe talk about one of my papers that came out recently. But then I thought, nah, that's too easy… and I decided to show you a working in progress, which are results I got from my previous post doc in Gothenburg (Göteborg), Sweden. For the 2nd half I'll show the questions I'm trying to answer right now with the current post doc project, and hopefully receive some feedback. So as I said I did a post post in Gothenburg in 2015, spent 6 months there (short project), and then I moved back to Brazil and started four months ago with this new project.

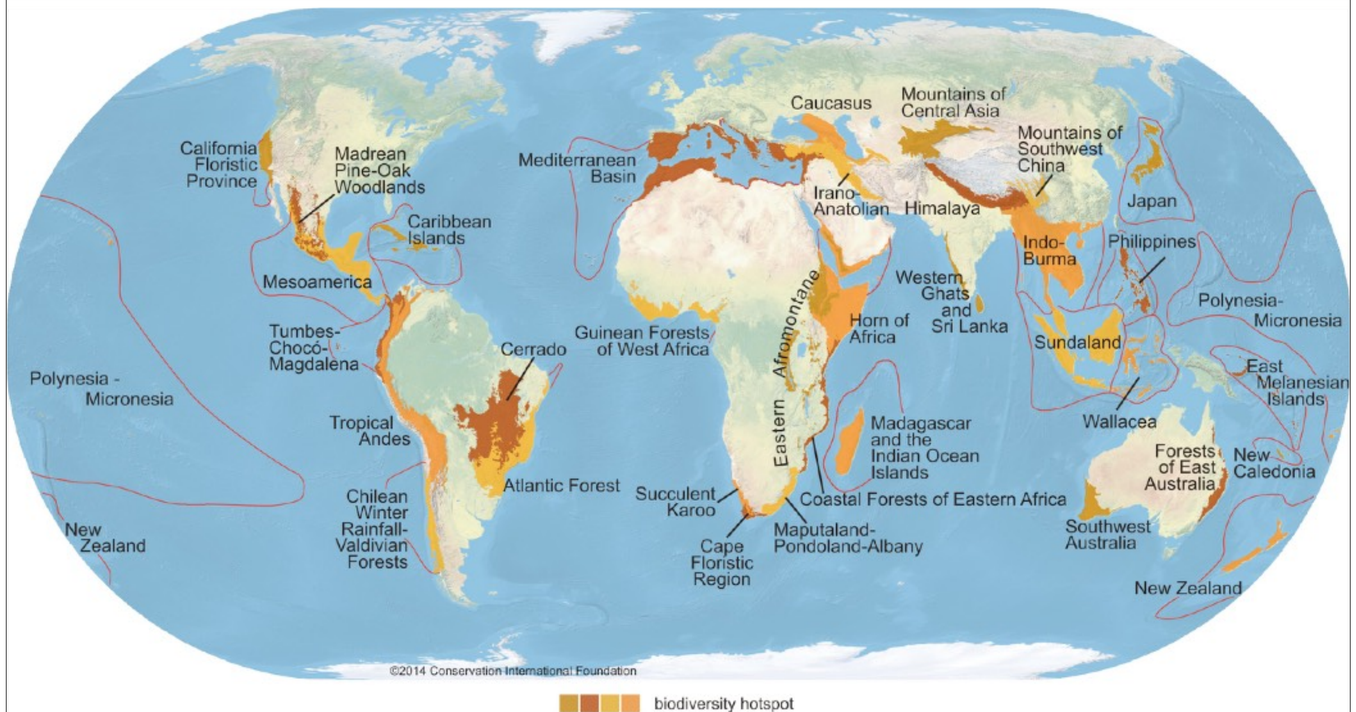
1. Background – The Atlantic Forest (Hotspot)
   - Models for explaining biodiversity in AF
   - Anuran amphibians diversity in AF

2. Results from previous post doc at Göteborg, Sweden
   - GeoSSE – rates of speciation and extinction between refugia/non-refugia
   - Phylogenetic community structure
   - Partitioning PhyloBetaDiversity – nestedness-resultant and turnover

3. Quick overview of the questions of my current project
   - Linking macroevolutionary and ecological mechanisms to understand current distribution of vertebrate diversity
   - Phenotypic hotspots
   - Equilibrium/non-equilibrium mechanisms
   - Adaptive landscape of body size and clutch size evolution
   - Role of climatic niche on the rate of evolution of body size in a continental fauna

- Almost a third (26.6%) of the Brazilian population is concentrated along the East cost.
- 11.4 - 16 % of the original coverage remains
- Many endemic species
  - ~ 92% of AF amphibians are endemic to this biome

Ribeiro et al. 2009 Biol. Conserv.

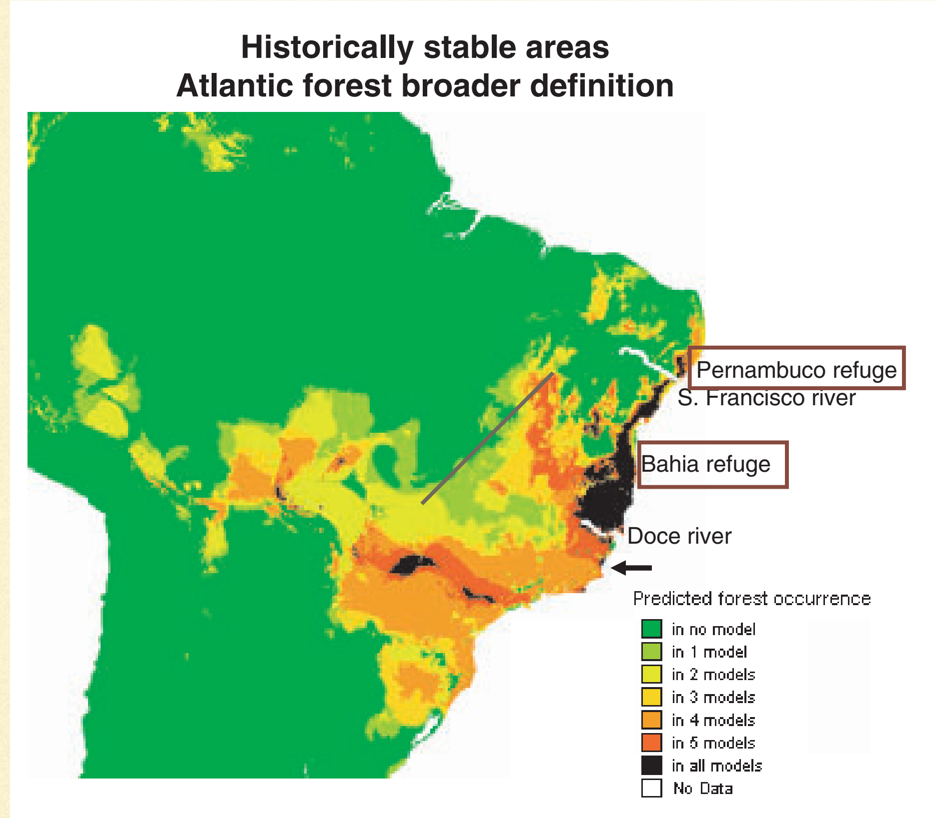


Conservation International (conservation.org) defines 35 biodiversity hotspots — extraordinary places that harbor vast numbers of plant and animal species found nowhere else. All are heavily threatened by habitat loss and degradation, making their conservation crucial to protecting nature for the benefit of all life on Earth.

MODELS TO EXPLAIN AF BIODIVERSITY

- Climatic stability throughout the Pleistocene
  - Imprint on present species composition and intraspecific lineage diversification
  - Climatic refugia may have contributed to species diversification
  - Phylogeographical studies found expanding populations in southern AF

Carnaval et al. 2009 Science, Carnaval & Moritz 2008 J. Biogeog



Carnaval & Moritz 2008 J. Biogeog

- Geographic barriers (e.g., Mountain ranges of southeast)
  - Allopatric and parapatric speciation
    - (most) Anurans are highly dispersal limited, depend on humidity
  - Many small-ranged species in the AF
  - Strong environmental gradients that could foster ecological specialization

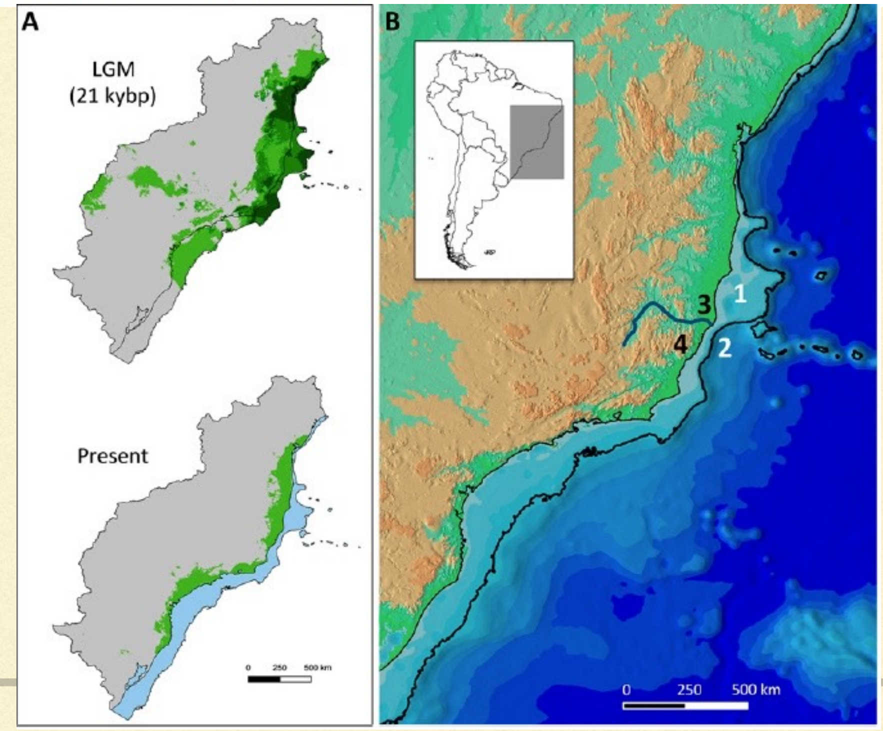
Villalobos, Provete et al. 2011 PLoS One, Thome et al. 2008 Mol. Ecol

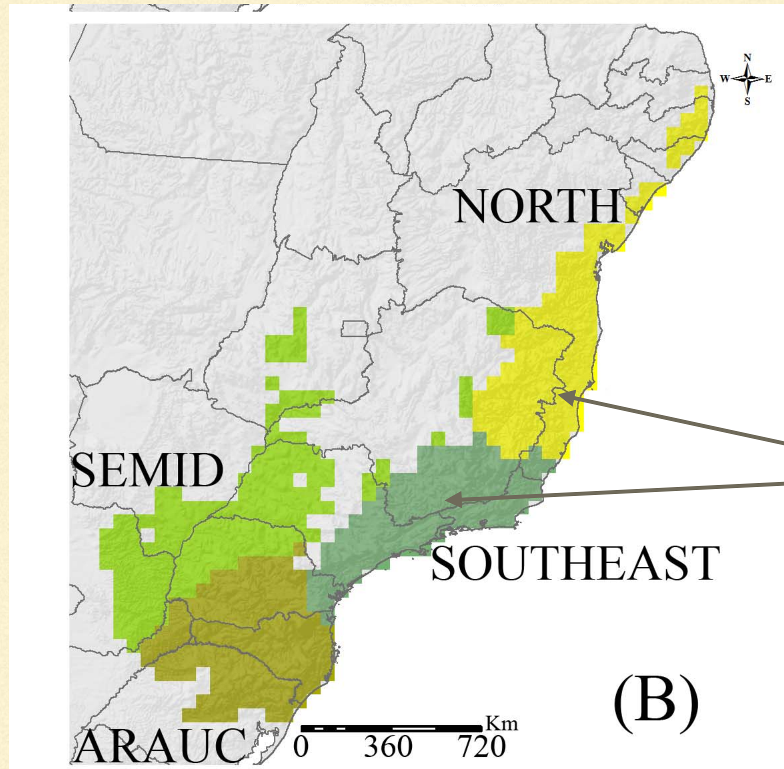
- ”Atlantis" Forest Hypothesis
- Forest expansion during LGM into the [now submerged] continental shelf
  - Against the ”refugia hypothesis"
- DNA coalescence model for small mammals
  - Increase of suitable areas all most species

1008–1013 | PNAS | January 26, 2016 | vol. 113 | no. 4

Neotropical forest expansion during the last glacial period challenges refuge hypothesis

Yuri L. R. Leite[a,1], Leonora P. Costa[a], Ana Carolina Loss[a], Rita G. Rocha[a,b], Henrique Batalha-Filho[c], Alex C. Bastos[d], Valéria S. Quaresma[d], Valéria Fagundes[a], Roberta Paresque[e], Marcelo Passamani[f], and Renata Pardini[g]





Regionalization based on taxonomic species composition

Marked differences in species composition

Vasconcelos et al. 2014

and what we end up with, at least for amphibians, these marked differences in species composition along the atlantic forest that we try to explain

[WORK IN PROGRESS]

WHAT WE DID SO FAR

- Testing the role of pleistocene climatic refugia on anuran amphibian species distribution in the AF
  - Partitioning phylobetadiversity (turnover and richness difference components)
  - Phylogenetic community structure
  - Differential diversification rates - GeoSSE


Atlantic Forest
Refugia
(Carnaval and Moritz model)

531 species

Green = occur in both regions
Blue = refugia endemic
Red = endemic to non-refugia

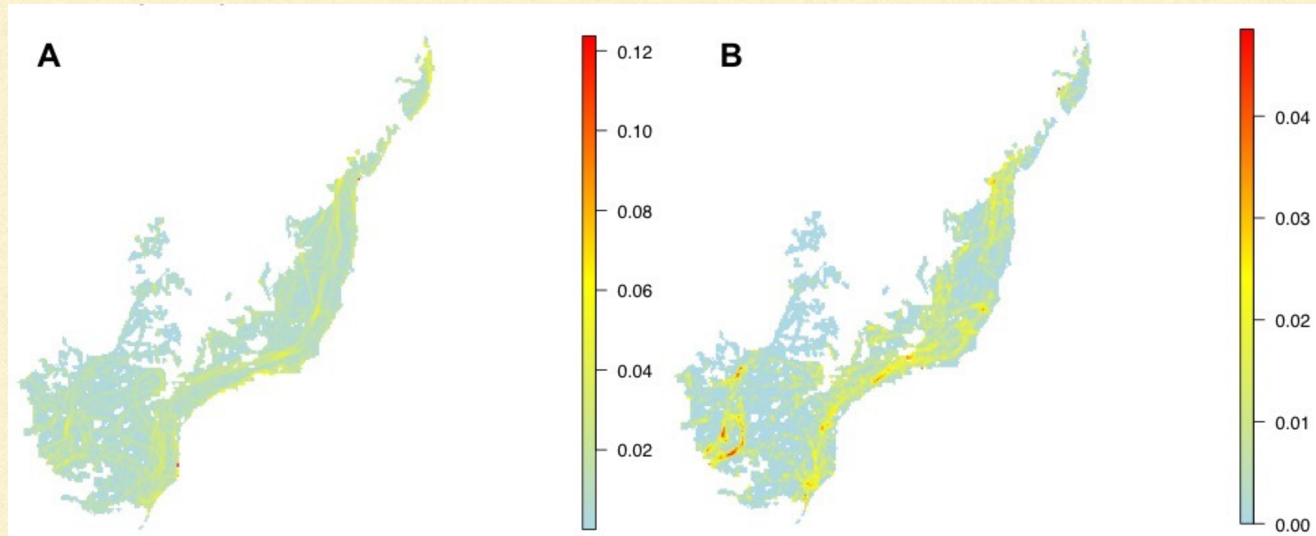
AF species that have polygons in the IUCN. prunned the phylogeny Pyron. We also coded the species regarding their endemism level

- **Expectations**

- More nestedness between refugia and non-refugia
- Turnover between refugia

Mean of richness difference

Mean turnover



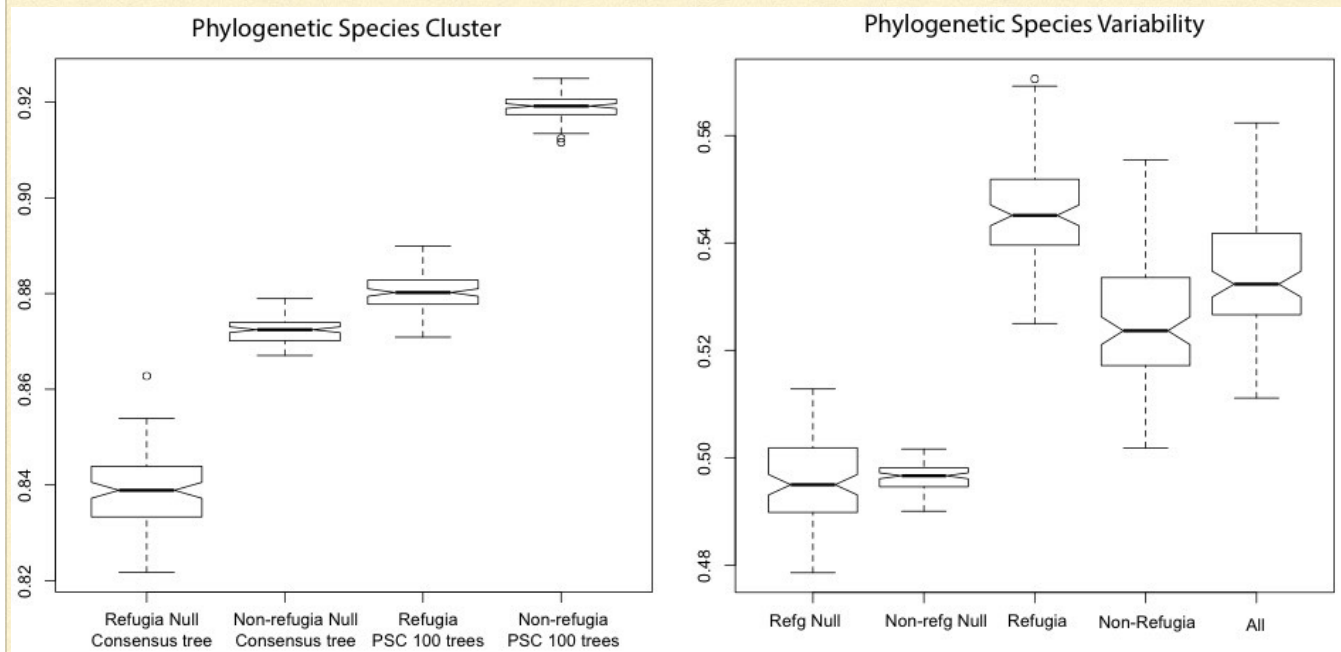
- No clear pattern between refugia and non-refugia regions, as expected.

- No richness differences between refugia and non-refugia

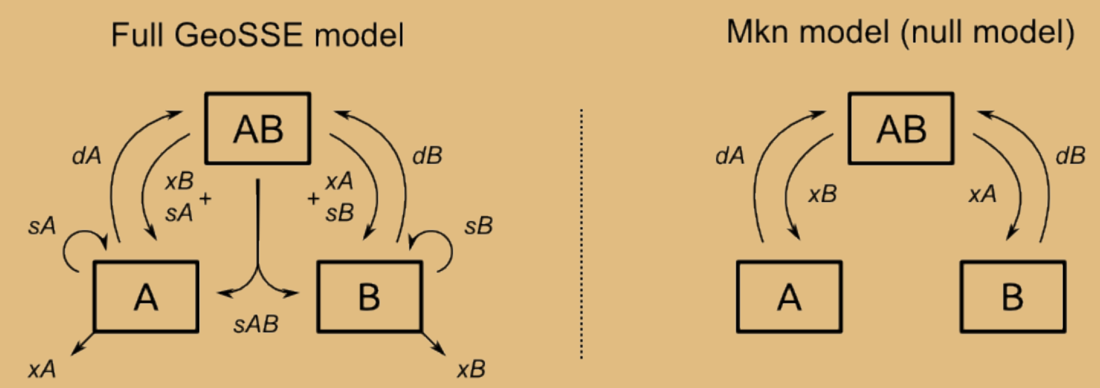
- Instead, mountaneous regions, like the Serra do Mar in the southeast, border betweeen AF and other biomes, and the Bahia refugium, have high values for turnover

The predictions would only make sense if the lineages that are endemic to refugia were closely related…

… instead, they are overdispersed in the phylogeny



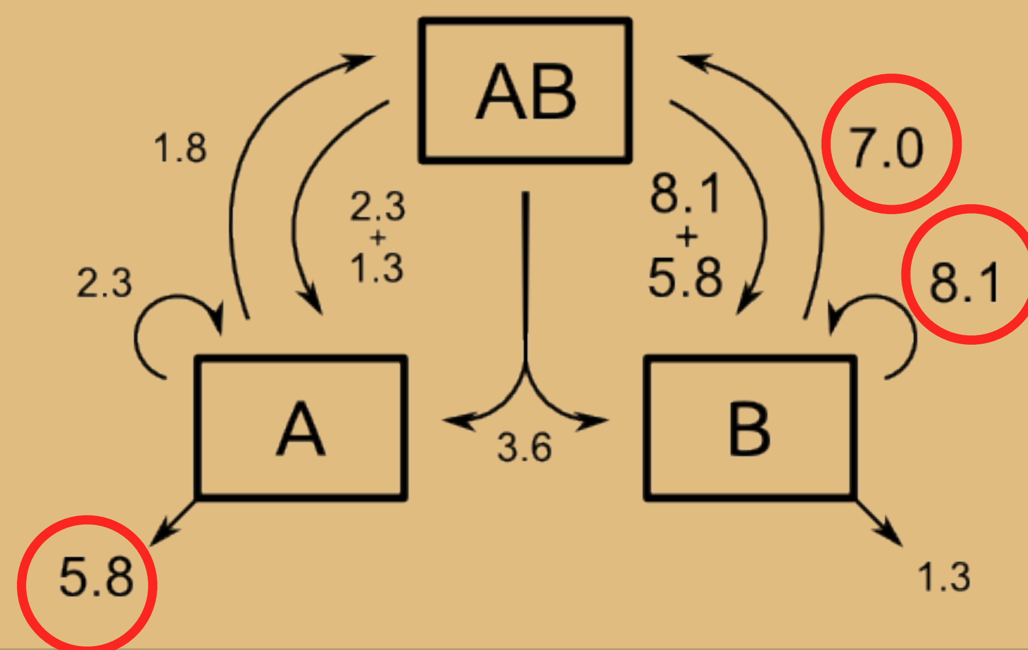
- The distribution of endemic species to refugia vs non-refugia along the phylogeny is not random, compared either to the null model or to the species pool of the Atlantic Forest
- **Conversely, refugia endemic lineages are more phylogenetically distant than the endemic to non-refugia**, compared to the species pool of the AF
- **This suggest that many lineages (e.g., different families) are endemic to refugia**
- Traits that may be associated with endemism in refugia may have have evolved several times



x = extinction rate
s = speciation rate
d = range expansion

A = endemic to refugia
B = endemic to non-refugia
AB = both

MLE of full GeoSSE model

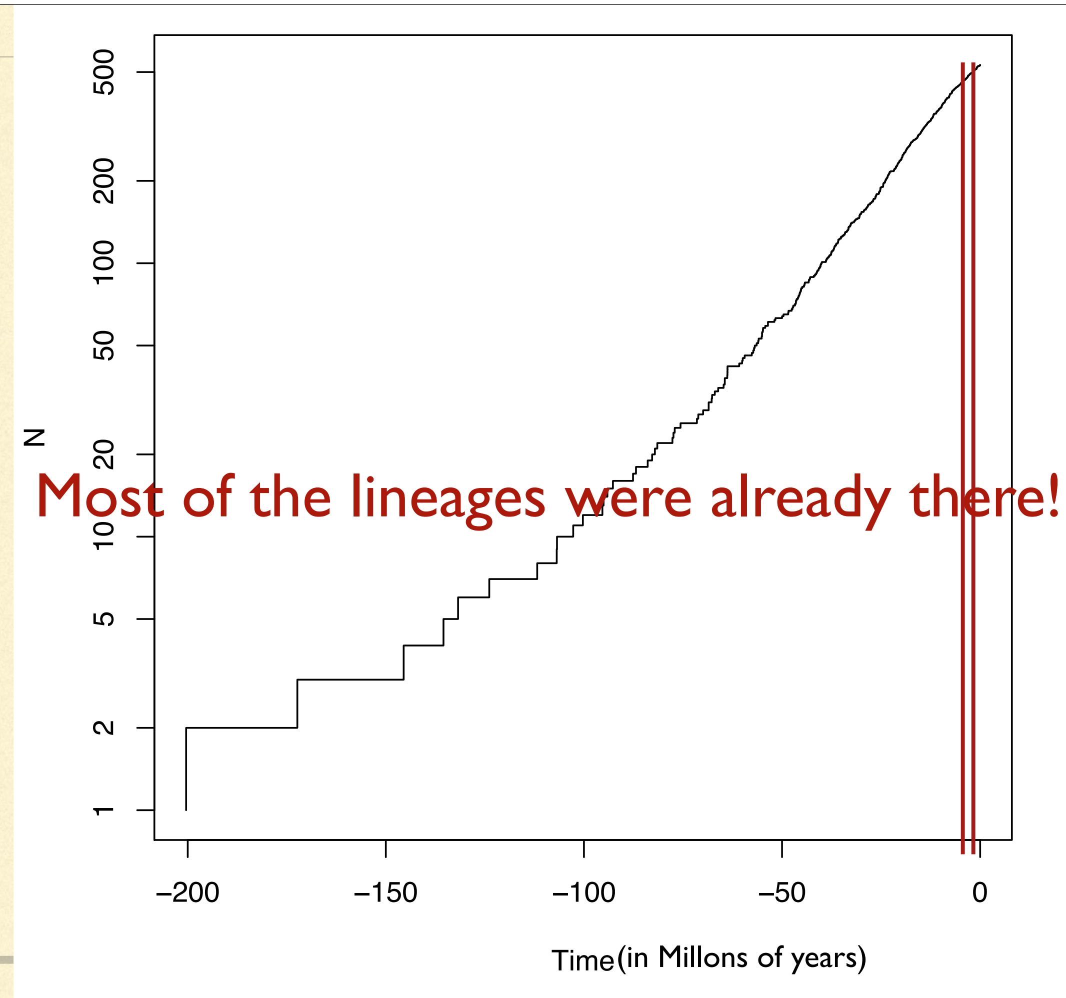


WHAT THE RESULTS MEAN

- Species endemic to refugia have lower rates of range extension than other species
  - Contrary to our expectations, but…
  - Makes sense if endemic species were "specialists"
- Speciation is higher in less stable regions
  - Areas with higher perturbation frequency, and then varying selective pressures promote higher speciation in a broad scale
- Higher speciation rates in non-refugia suggest diversification in AF as a whole is not dependent on refugia alone

Conclusion

The refugia from the Plio-Pleistocene seem not to have generated the species diversity of anurans in the Atlantic Forest, since most species are older than the refugia itself… but how do I known that?



This is a lineage through time plot of the phylogeny for the AF species

Conclusion

Probably, refugia were important to maintain genetic diversity at the intraspecific level, as phylogeographical studies have demonstrated (e.g., Carnaval et al. 2009; Tonini et al. 2013), but are not strongly involved in species diversification *per se*.

Next steps

Test for an effect of refugia, current, and past climate on the metacommunity structure of anurans

- For example, is the distribution of species endemic to refugia more correlated with past climatic conditions due to Phylogenetic Niche Conservatism?
- Are communities in refugia older than in non-refugia?

Leibold et al. (2010) Ecol Lett

Patterns and processes in the origin and diversification of terrestrial vertebrates in the Brazilian Atlantic Forest

Supported by FAPESP #2016/13949-7

- Multi-taxa evaluation of distribution patterns
  - Non-volant mammals
  - Anurans
  - Birds

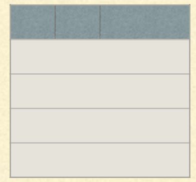
Causes of the spatial distribution of functional diversity of terrestrial vertebrates in the Brazilian Atlantic Forest

QUESTION

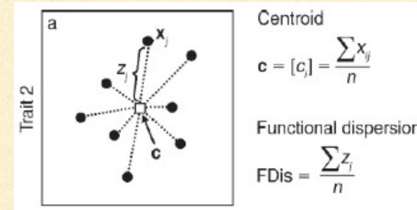
- **How equilibrium and non-equilibrium mechanisms interact to shape the species richness and functional diversity of vertebrates in the AF.**

- To distinguish the contribution of equilibrium and non-equilibrium mechanisms, I will test how speices richness and functional diversity are related with evolutionary time, diversification rate, productivity, climatic variables, and topographic heterogeneity.

Traits



FDis



Map FDis

For each group separately

Topographic heterogeneity

Climatic variables

Diversification rate

Productivity

Evol time (MPD)

Structural Equation Modelling using GLS

HYPOTHESIS

- If equilibrium mechanisms were more important, I expect that current climatic variables and gradients of productivity are strongly and positively related to species richness and functional diversity.
- Climatic seasonality would be a strong environmental filter, constraining the niche space available in regions with more seasonal climate, decreasing its functional diversity.
  - This effect should be more marked for poikilotherms than homeotherms

Oliveira et al. 2016 Glob. Ecol. Biogeog | Wiens et al. 2006 Am Nat

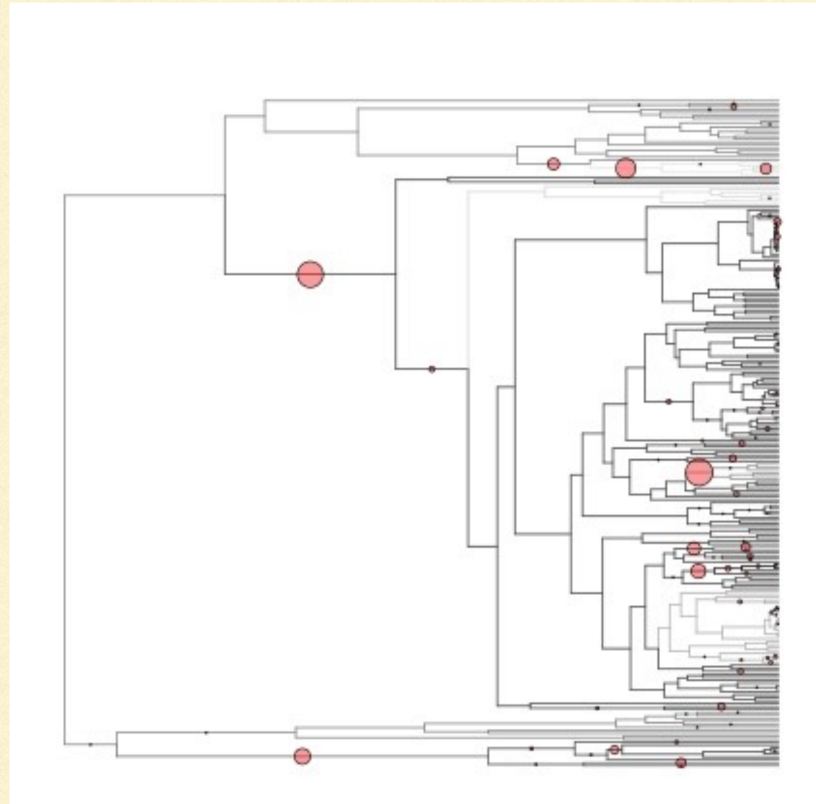
Adaptive dynamics of functional traits along the phylogeny

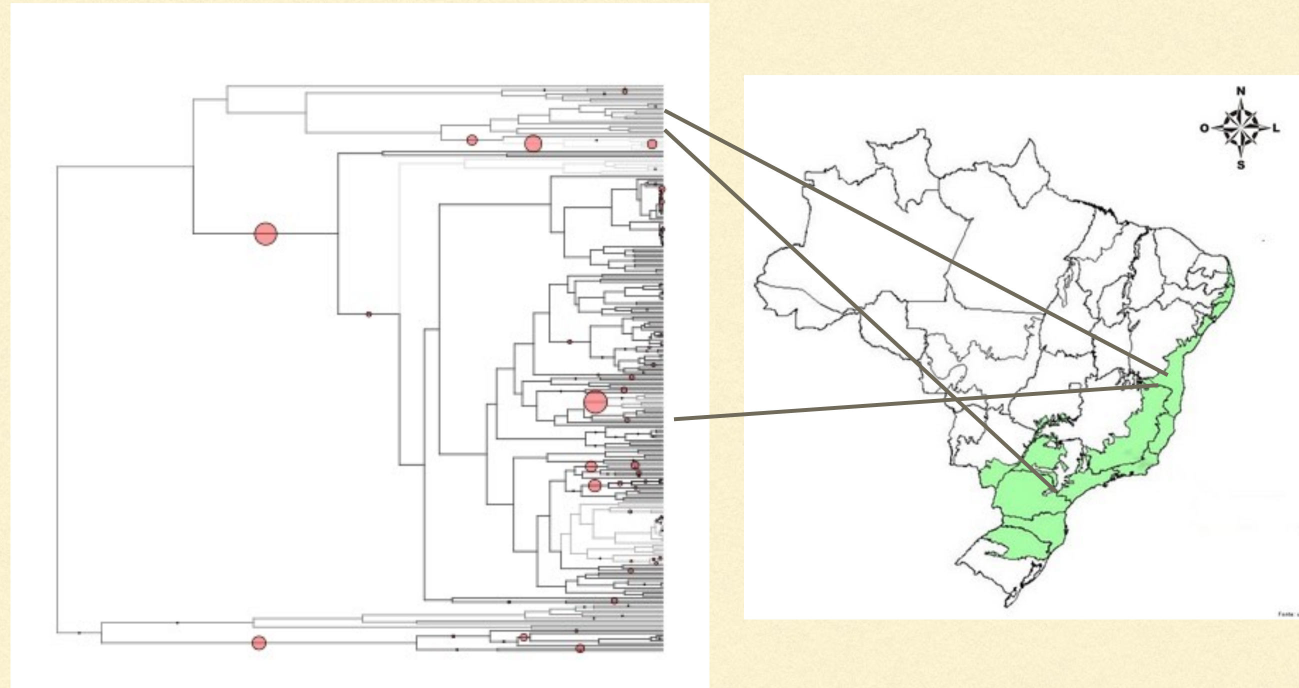
QUESTION

- Is there phenotypic convergence for **body size** in distantly related lineages that occur in the same region (e.g., distant species that would expand their populations towards the south of the AF recently) ?

Clavel & Morlon 2017 PNAS

R package bayou
multi-regime OU model

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HYPOTHESIS

- Patterns of phenotypic convergence can indicate that distant lineages are under the same selection regime, suggesting that environmental factors are important to determine the variation in traits.
  - Example, environments with harsh climate (highly seasonal) strongly constrain the variation in traits at the community level

Mahler et al. 2013 | Webb et al. 2002

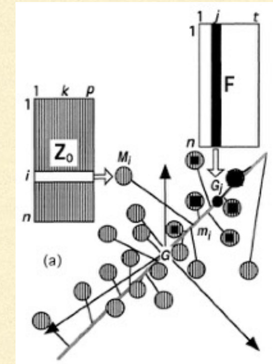
Influence of the climatic niche on the rate of phenotypic evolution

QUESTION

- Assuming that diversification rates are correlated with rates of phenotypic evolution…
- Did climatic niche evolution influence phenotypic variation of species at broad spatial scales?

Rabosky & Adams 2012 Evolution | Rabosky et al. 2013 Nat. Comm. | Lawson & Weir 2014 Ecol. Lett

Climatic variables
CHELSA

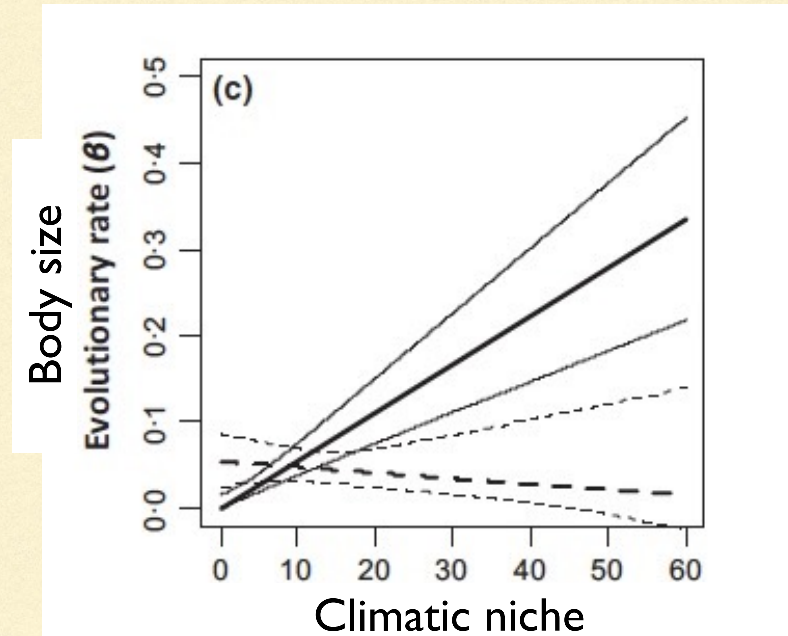


OMI

Extract eigenvectors to describe the climatic niche

Estimate evolutionary rate

- R package EvoRAG



WHAT DO I EXPECT?

- Gradients of temperature and rainfall seasonality are important to differentiate the climatic niche of species.
- On its turn, the niche will influence the rate of trait evolution (e.g., body size) differentially for the three groups, due to different thermal tolerances
  - More strong in poikilotherms (amphibians) than in homeotherms (birds and mammals)
  - Differences in the north (warmer and more stable) and south portions of AF (cooler and unstable) => groups with life history traits adapted to each region

Carnaval et al. 2014 Proc. Royal Soc.

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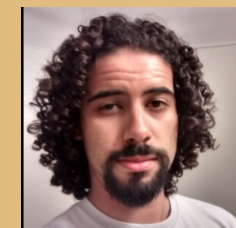

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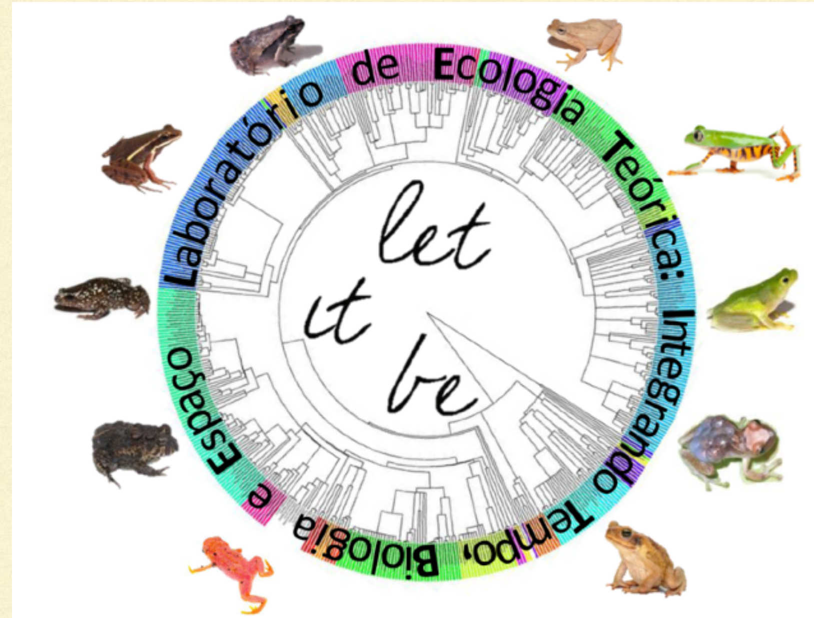
CIÊNCIA
SEM FRONTEIRAS



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