The Assembly and Evolution of the Amazonian Biota and its Environment

Dimensions of Biodiversity US-BIOTA-São Paulo

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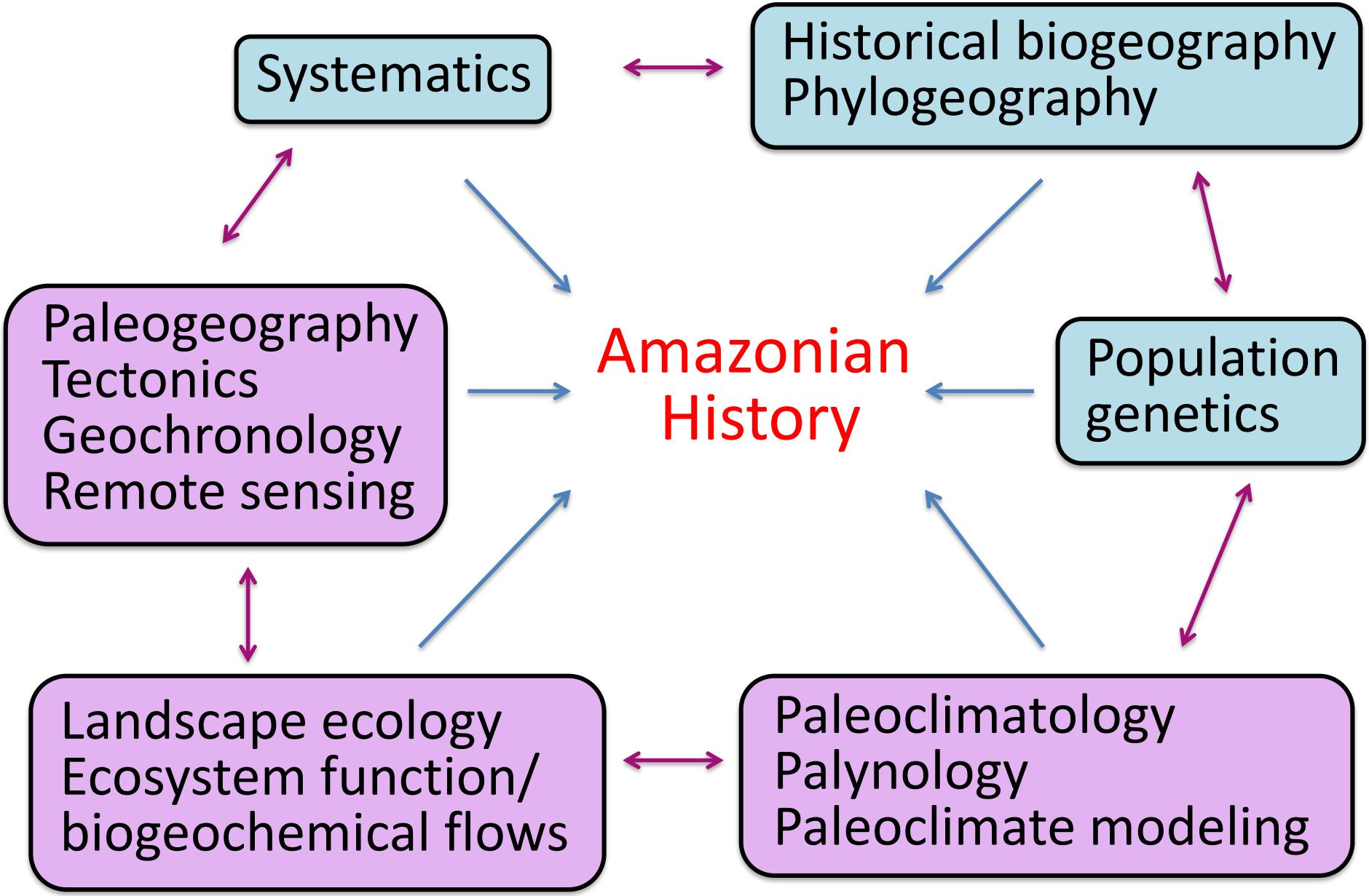
Scientific challenges and goals

- How is genetic, taxonomic, and ecological diversity distributed within Amazonia?
- What has been the evolutionary history of the Amazonian biota and how was it generated?
- How have Amazonia's biotic, geological, and climatic histories evolved together?
- What have been the global effects of this co-evolutionary system over time?

Requires a new integrated approach

Integration across disciplines



Some summary "statistics" in 7th year, with at least two more to come

- >210 published papers to date on plants, butterflies, birds, primates, Earth sciences, and data analysis
- 28 technicians/undergraduates, 41 Masters, 55 Ph.D., 26 postdoctoral fellows trained
- 58 items general outreach (blogs, magazine articles, web/video)
- multiple public lectures (including, audience of ~600 at AMNH)
- sponsorship of teacher training workshops at AMNH (5 over term of grant)

Some key findings

- The Amazon environment we see today (the expansive *terra firme* forest and the hydrological landscape) is not “old”
- The Amazonian landscape is hugely dynamic and has changed significantly, even over short geological time scales
- The species diversity we see today is largely very young, although many stem-lineages are older

Origin of transcontinental Amazon River remains highly controversial

Epoch	Dates (Ma)	Reference	Data type(s)			Region(s)	Source(s)
			Geochronology	Sedimentol.	Biostrat.		
Upper Miocene	12.6	Jaramillo et al., 2017	SI (13C)	ST, SL	PM, PO, MF	Lla, Wam	Mar. & Ter.
	11.6 - 11.2	Heinrich, Zonneveld, 2013		ST, SR	PM	Atl	Mar.
	10.5	Figueiredo et al., 2010	RM, SI (Sm-Nd)	ST, SL	PM	Atl	Mar.
	10.1	Caputo, Soares, 2016	ST*, SL*, SI* (U-Pb)	ST*, SM*		NSA	Mar. & Ter.
	10.1	Mora et al., 2010	FT*, RM*, SL*	ST*, SM*	PO*	Wam	Ter.
	10.1	Hoorn *et al.*, 2010	FT*, RM*, SL*	ST*, SM*	PO*, MF*	NSA	Mar. & Ter.
	9.0 - 10.0	Dobson et al., 1997; 2001		ST		Atl	Mar.
	9.5 - 8.3	Gorini et al., 2014	RM, SL	ST	PM	Atl	Mar.
	9.0 - 9.4	Hoorn et al., 2017	SL	SI	PO	Atl	Mar.
	8.7	van Soelen et al., 2017	SI (13C, Sm-Nd)	ST		Atl	Mar.
Pliocene	5.3 - 3.6	Latrubesse et al., 2010		ST, SM	MF	Wam, Sol	Ter.
	3.0	Noqueira et al., 2013		ST, SM	PO	Sol, Ama	Ter.
Pleistocene	2.5	Campbell et al., 2001; 2006		ST, SM, SR*	MF	Wam, Sol, Alt*	Ter. Mar.*
	< 1.0	Frailey et al., 1988		ST		Wam	
	< 0.78	Rossetti et al., 2015	OL	ST		Sol, Ama	
	0.019	Cremon et al., 2016	OL SI (14C)	ST		Sol, Ama	
Total		16	11	16	12	16	13

*Reporting/synthesizing data from previous papers.

J. S. Albert, P. Val, C. Hoorn. 2018.
Neotropical Ichthyology vol.16 no.3

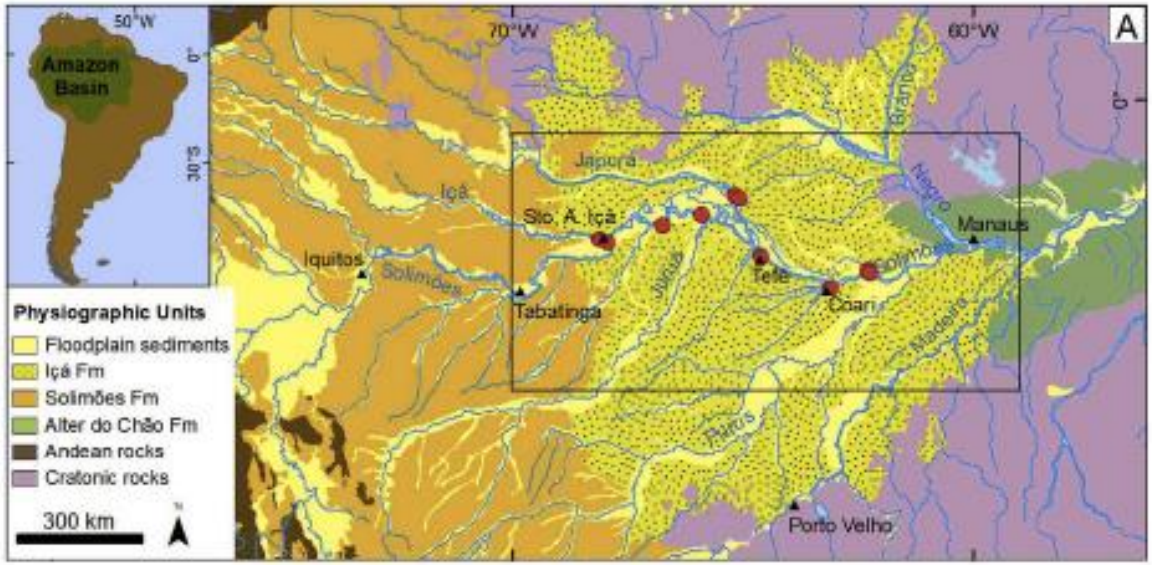
A partial explanation for *some* young species: dating the formation of *terra firme* forest along Solimões

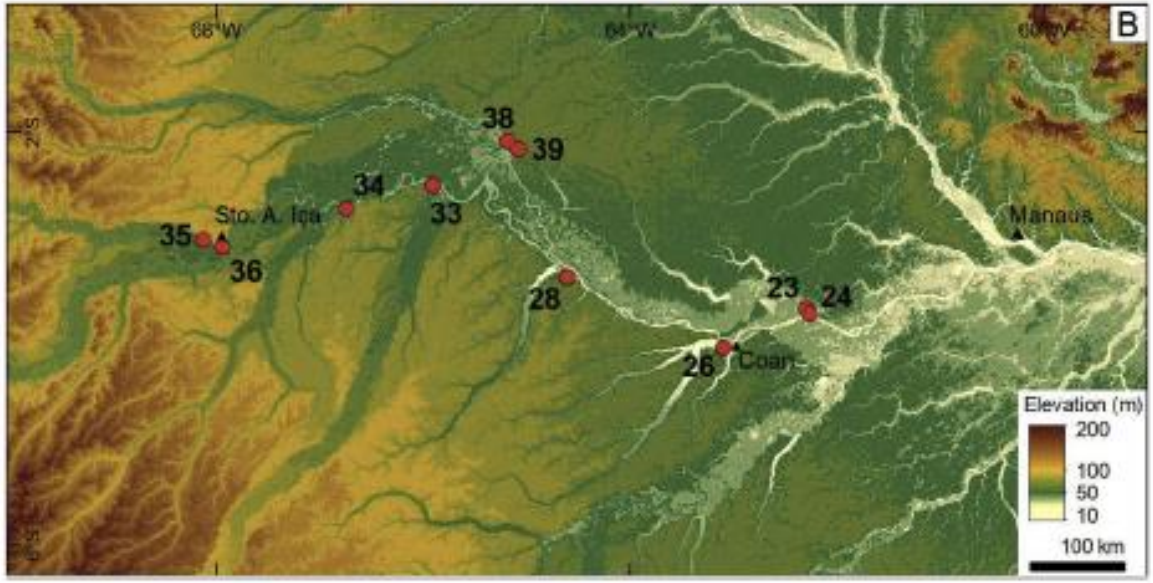
Dating the terraces

optically stimulated luminescence (OSL) dating

magnetostratigraphy

palinostratigraphy.





Pupim et al. 2019. *Quat. Sci. Rev*. 210 :154-163

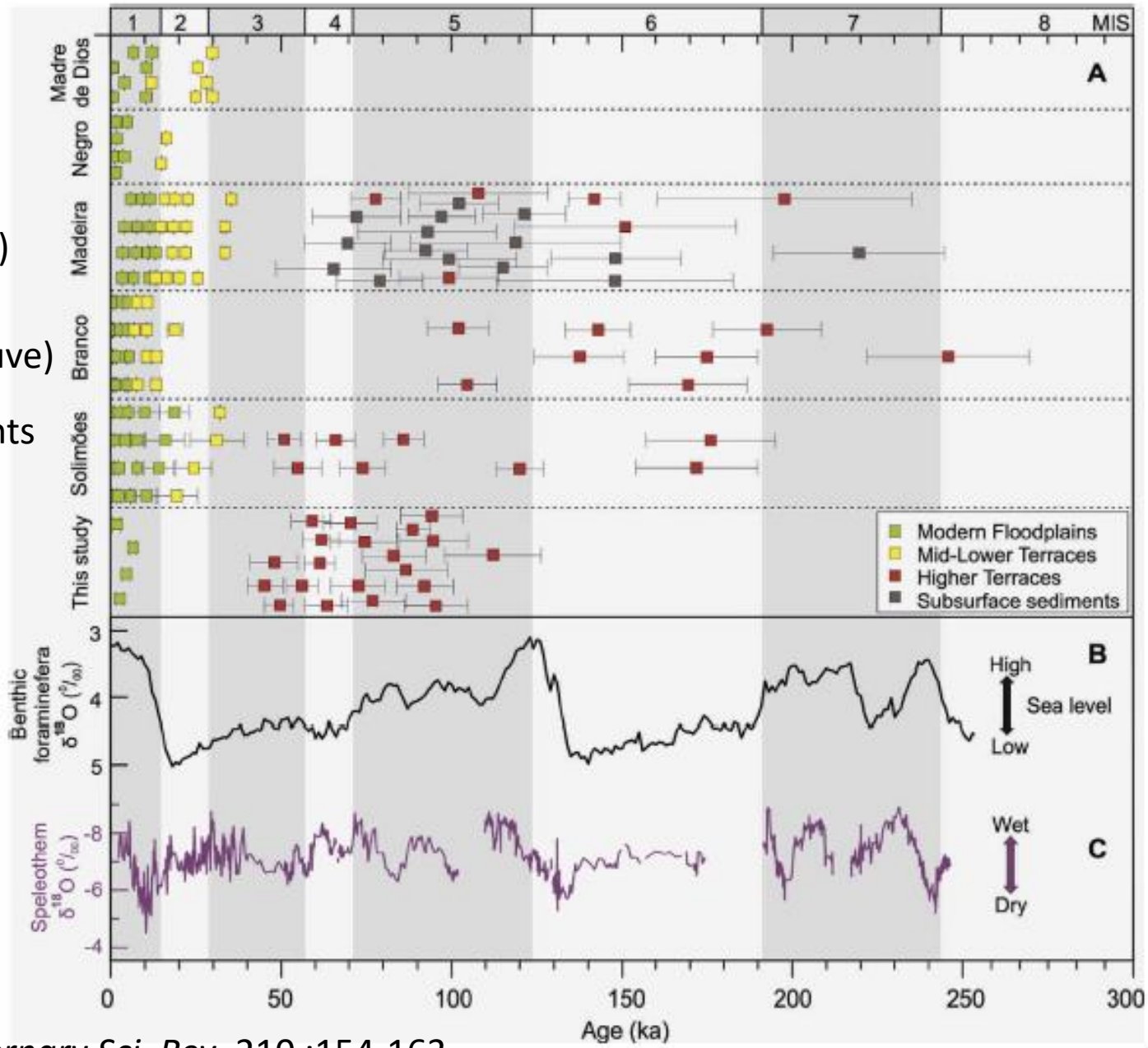
Terra Firme formation Amazon lowlands

Modern floodplains (Várzea forest)

Mid-lower terraces (non-flooded forest)

Higher terraces (Terra Firme interfluve)

Subsurface sediments (older deposits)

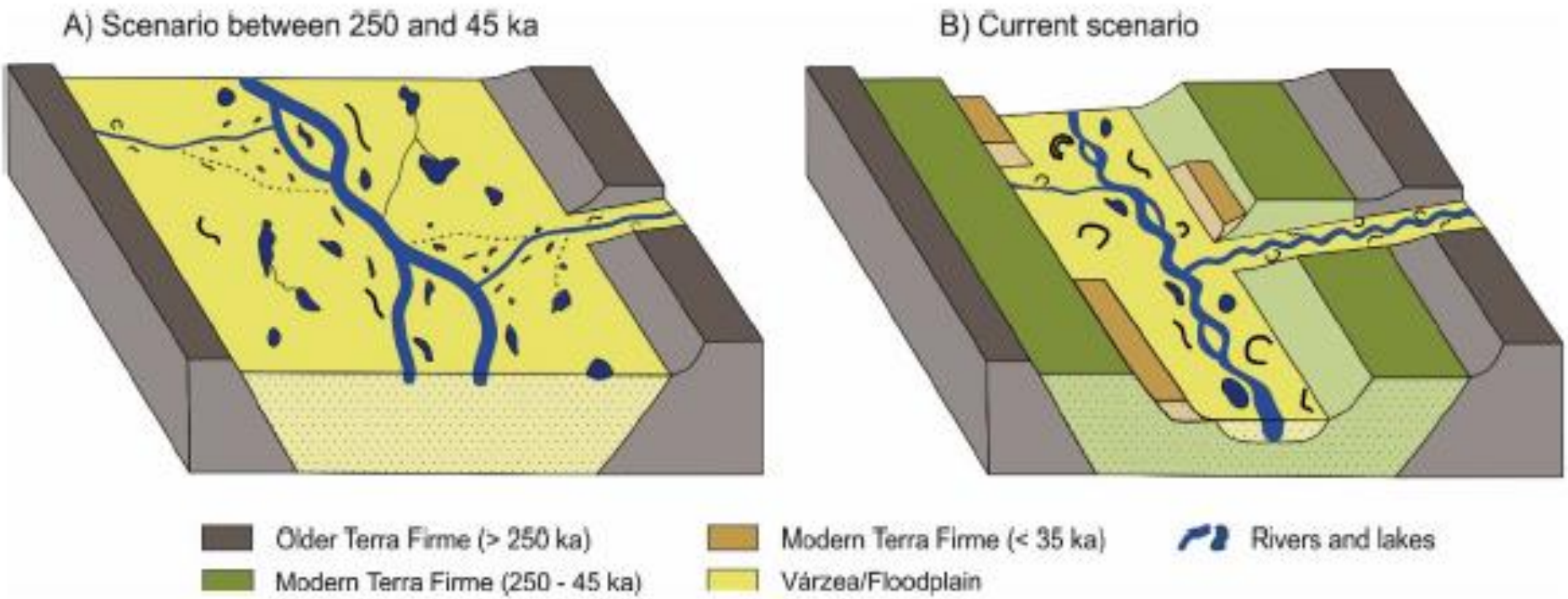


Pupim et al. 2019. *Quaternary Sci. Rev*. 210 :154-163

Paleogeographic origin of *Terra Firme*

Landscape dominated by Várzea
in dynamic channels

Regional drop in base levels,
incised valley, expansion terra Firme

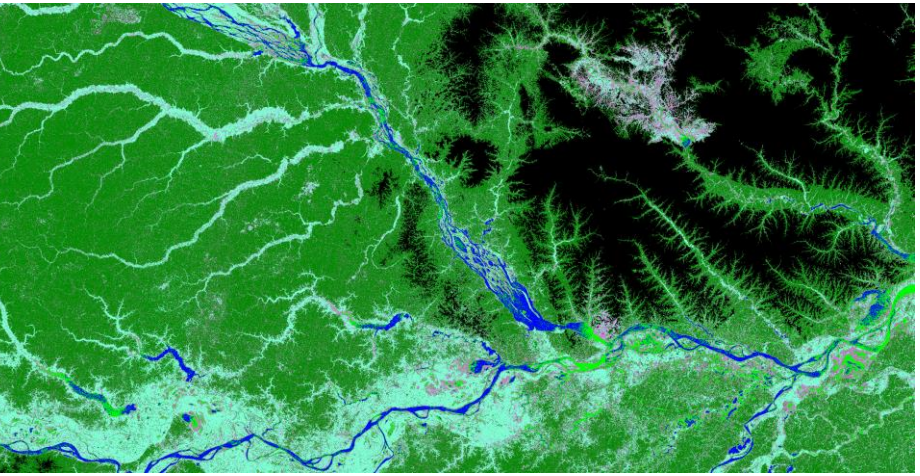


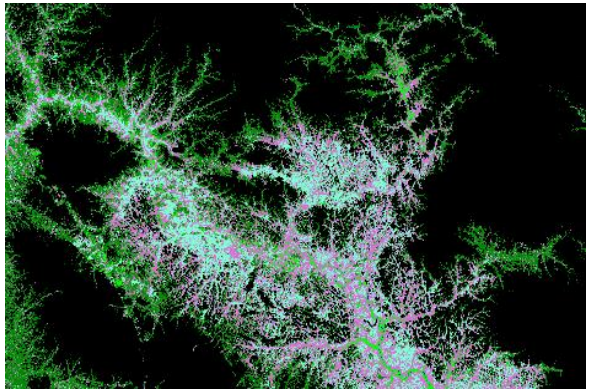
Middle to Late Quaternary

Pupim et al. 2019. *Quaternary Sci. Rev*. 210 :154-163

River dynamics and ecosystems: multiple studies using remote sensing

Flood Pulse Wetlands Inundation Dynamics from ALOS-2 PALSAR-2

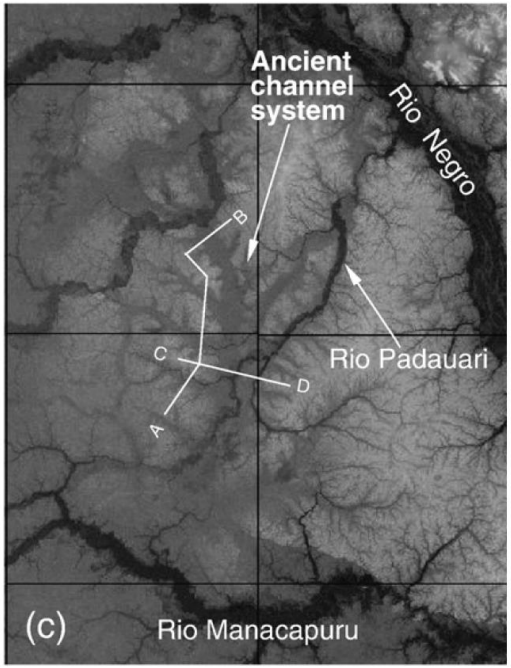




Open water
Inundated forest
Inundated non-forest vegetation
Terre Firme
Elevation > 75m

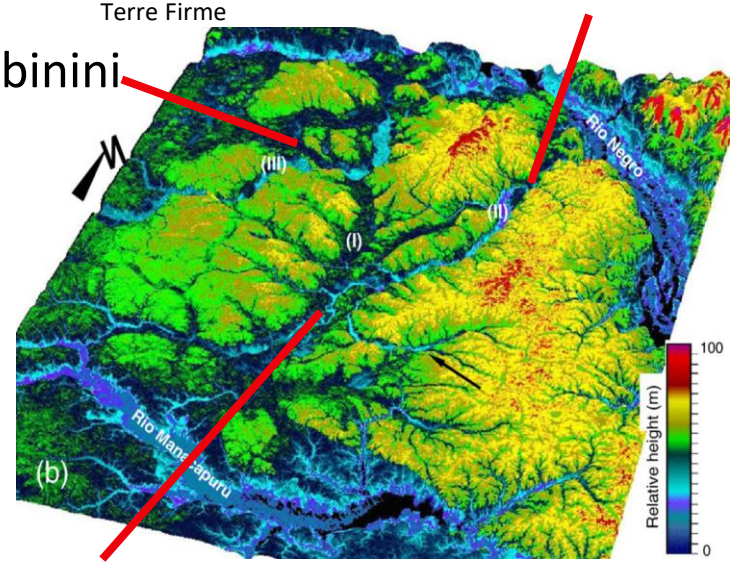
Lidar: white sands forest stand in a paleochannel north of Manaus, Brazil (Kyle MacDonald)

SRTM digital elevation model



Rio Padauari

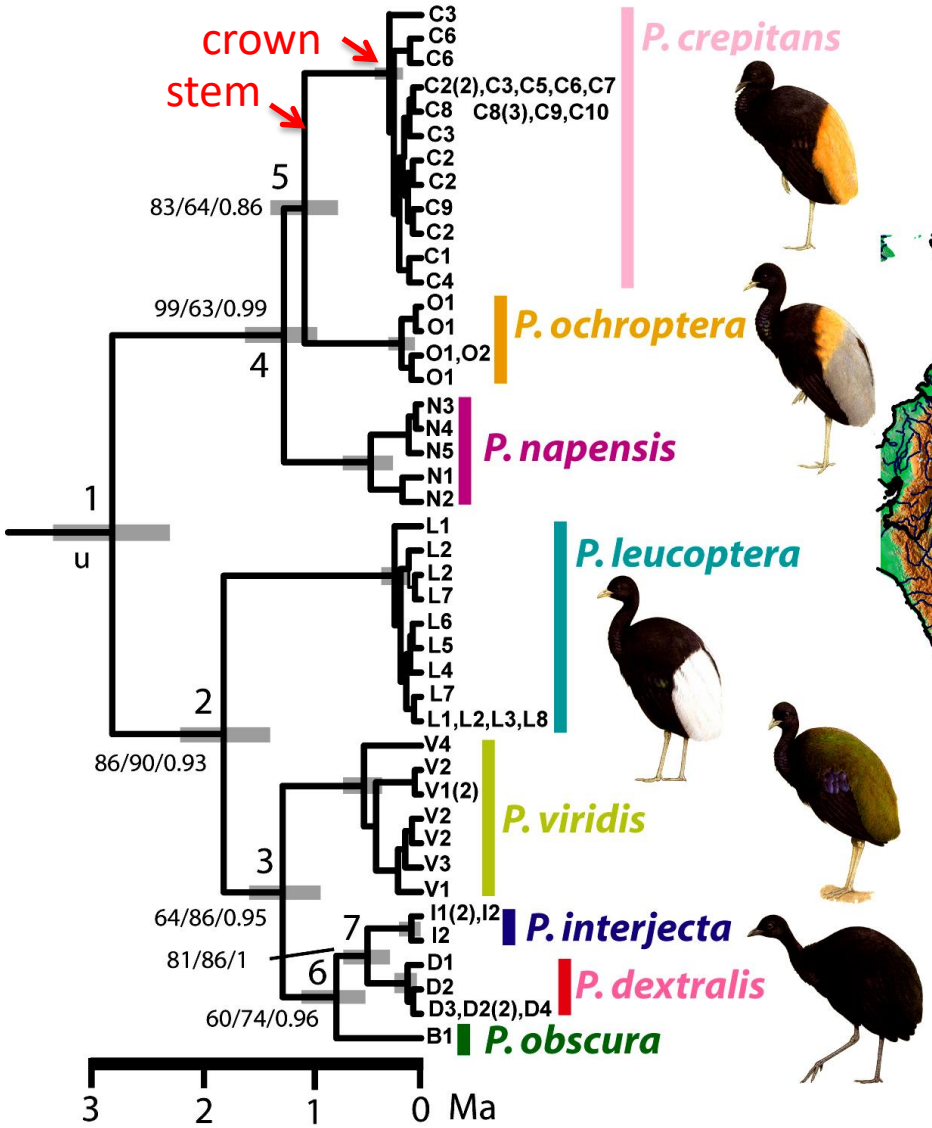
Rio Carabinini



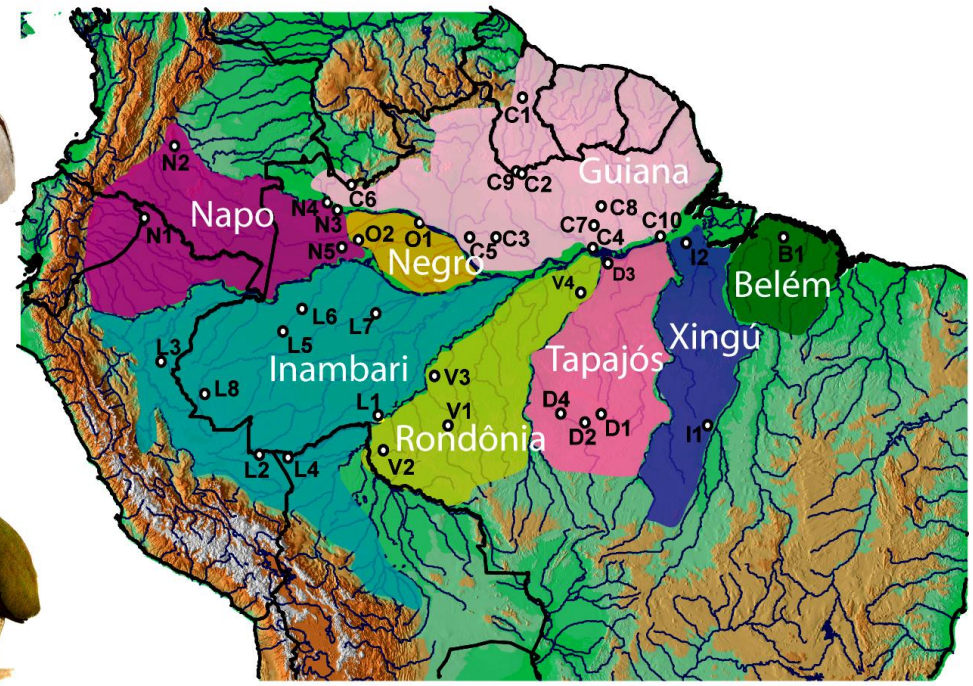
Almeida-Filho & Miranda. 2007. *Remote Sensing Environ.* 110:387-392

Amazonian species are commonly young: *Psophia*

Ribas et al. *PRSL* 2012



North Amazon/South Amazon east/west patterns



Timeline estimated by two independent methods

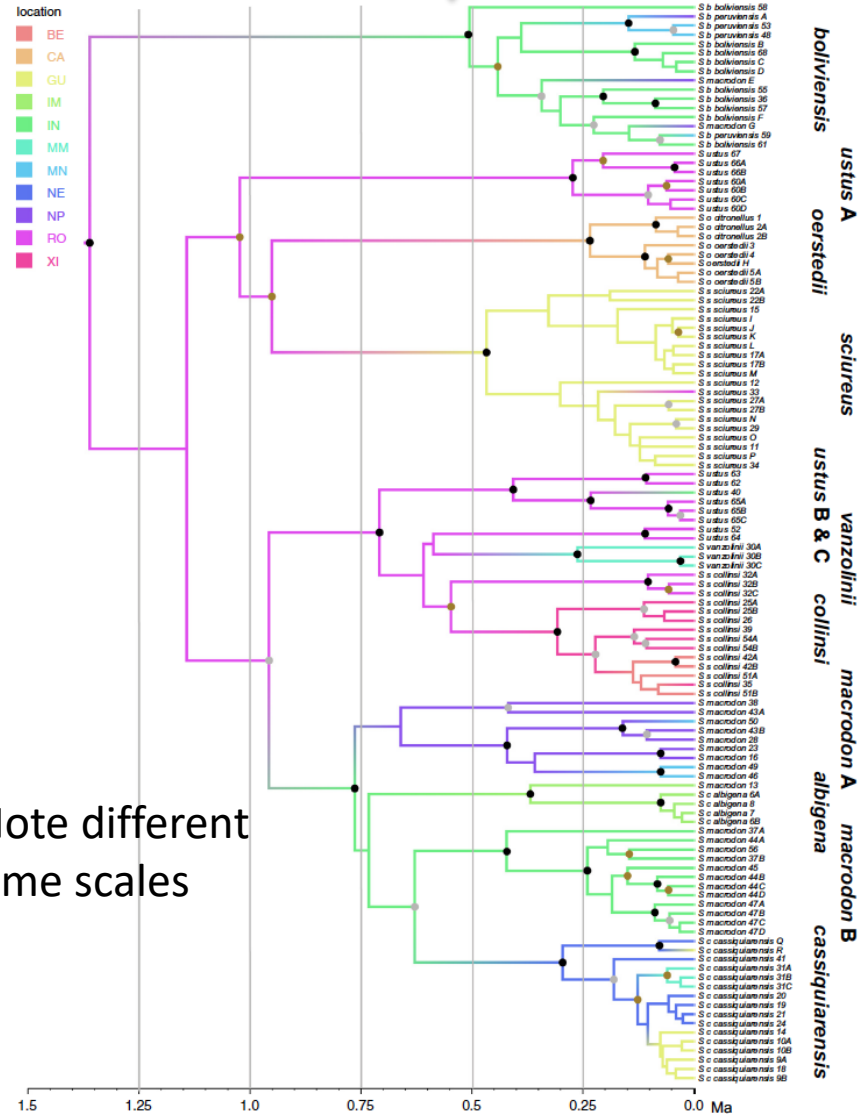
Leads to a predictive Amazonian paleogeography: testing alternative models

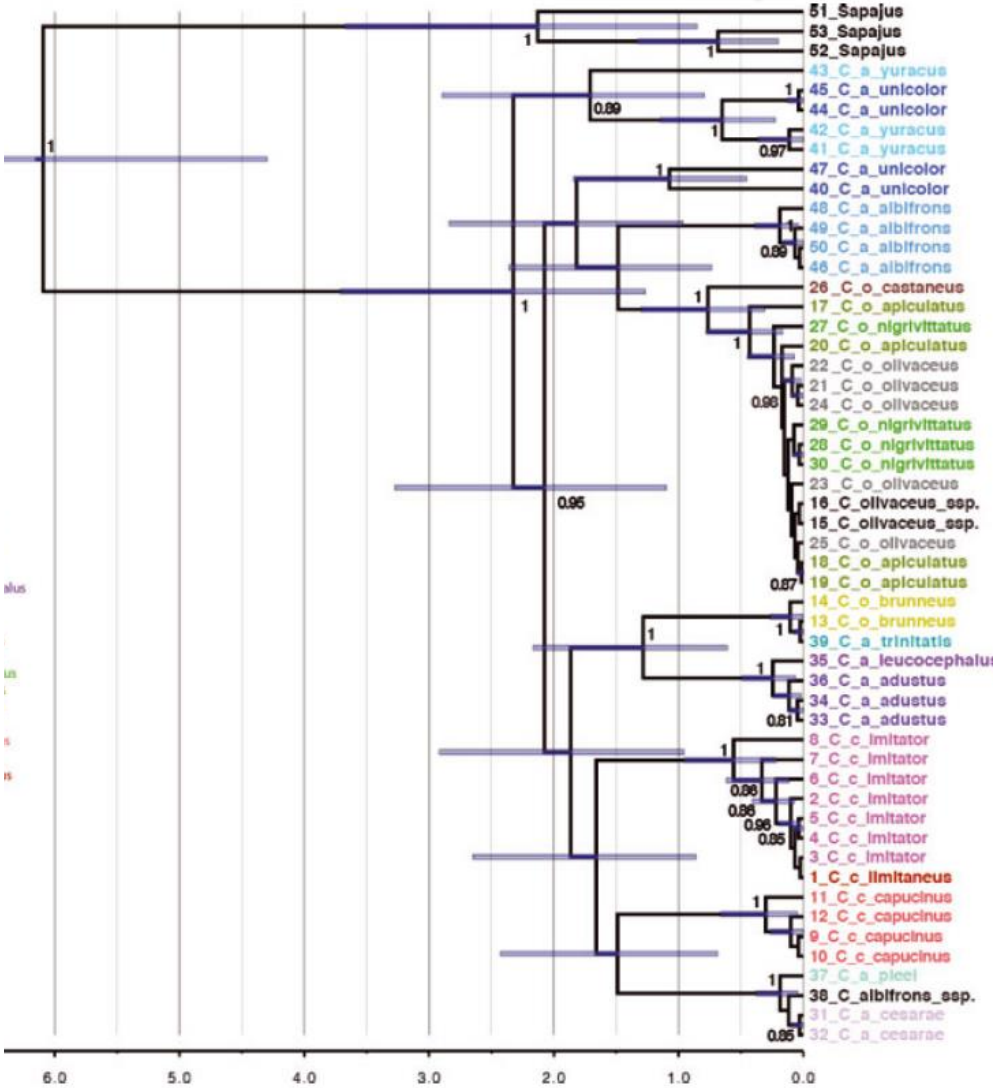
Ages of New World monkeys

crowns ↓

Saimiri (squirrel monkeys)

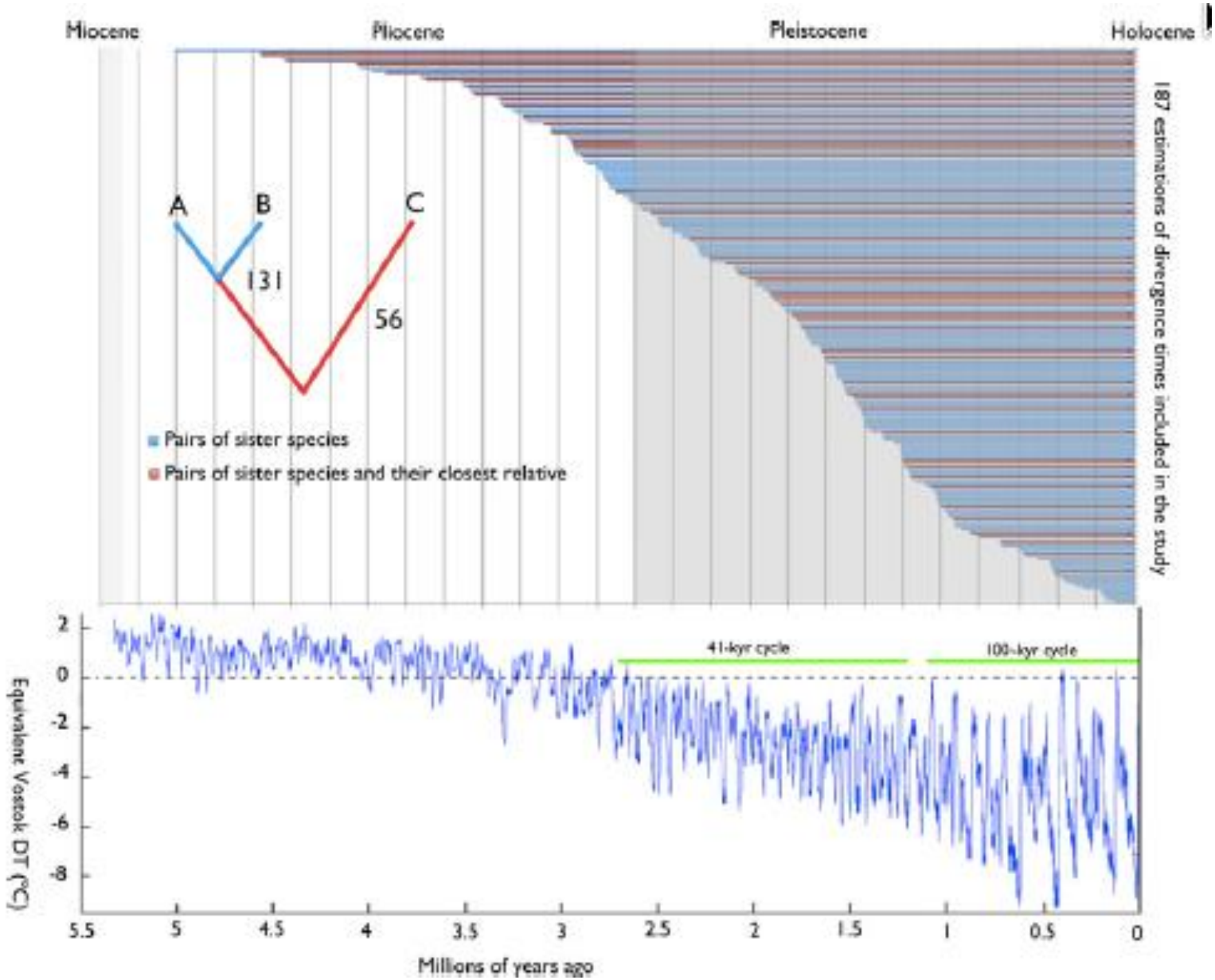
Cebus (capuchins)





Note different time scales

Ages of Amazonian butterflies



Garzón-Orduña et al. 2014. J. Biogeography 41, 1631–1638

Some conclusions about Amazonian history

- Amazonia's history is entangled with ancient connections to Gondwana and Laurasia
- Today's landscape, would have been unrecognizable in the mid-Miocene (~10 myr)
- A Miocene biota would have been less diverse, and distributional patterns would have been much different than today
- Only by taking an integrative approach can one reconstruct the "time-slices" of both paleogeographic and biogeographic history