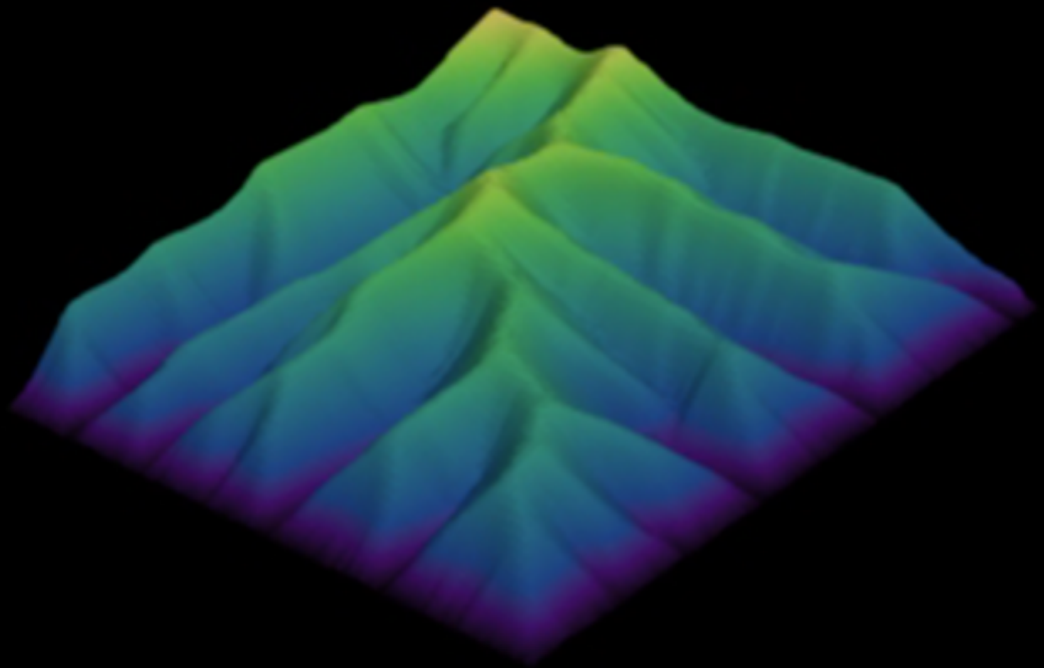
Life in Landscape Evolution Models

Investigations of Climate and Tectonics as Drivers of Biological Evolution

Nathan Lyons
Tulane University

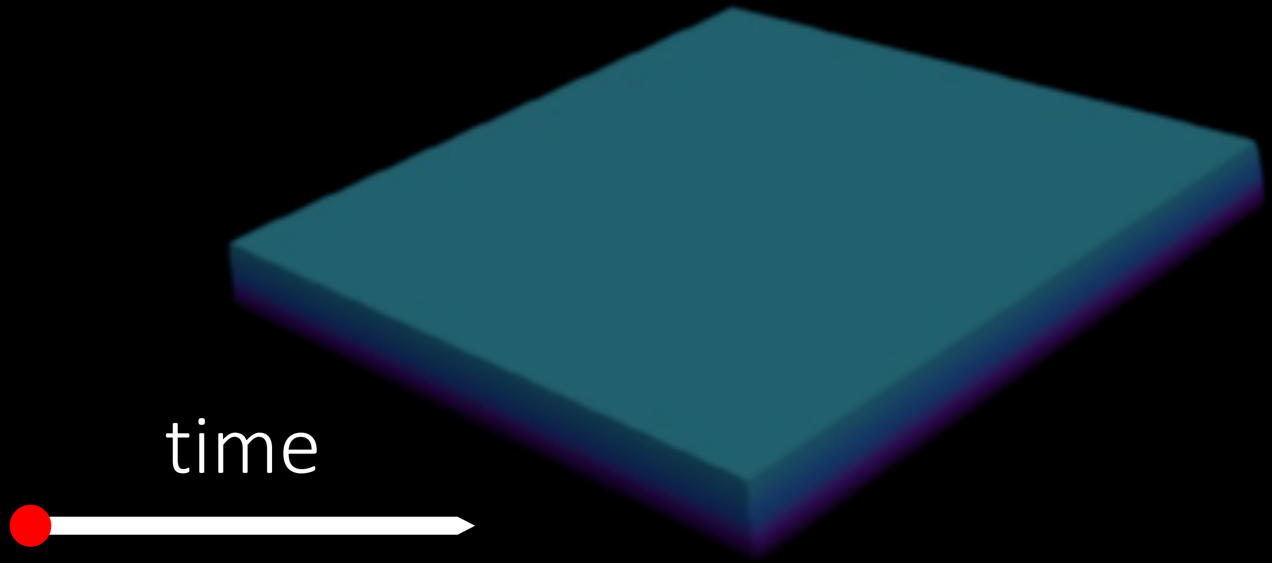


CSDMS Annual Meeting, May 20, 2020

A fundamental landscape evolution model

$$\partial z / \partial t = U$$

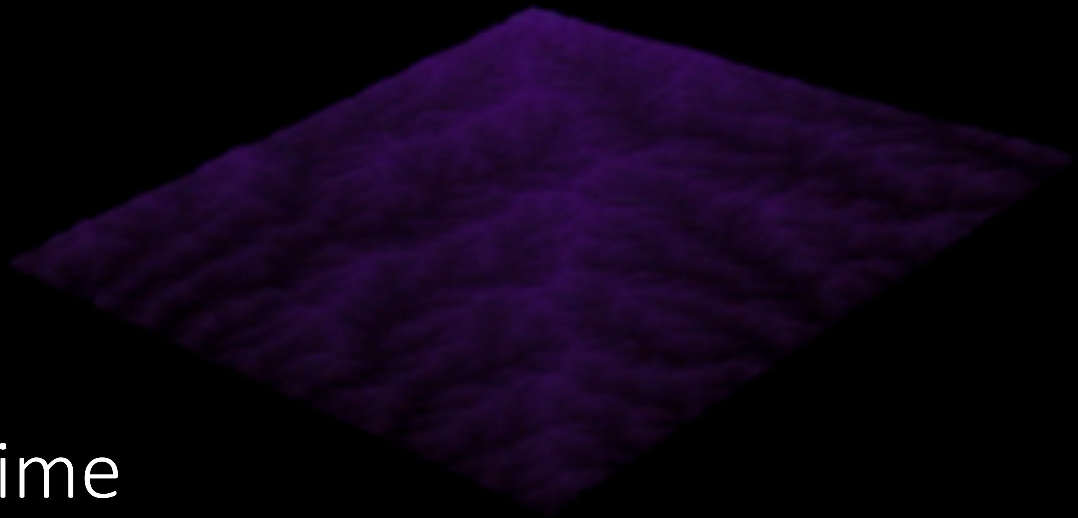
elevation over time = rock uplift



A fundamental landscape evolution model

$$ {\partial z}/{\partial t} = U - K A^m S^n $$

elevation over time = rock uplift − stream incision

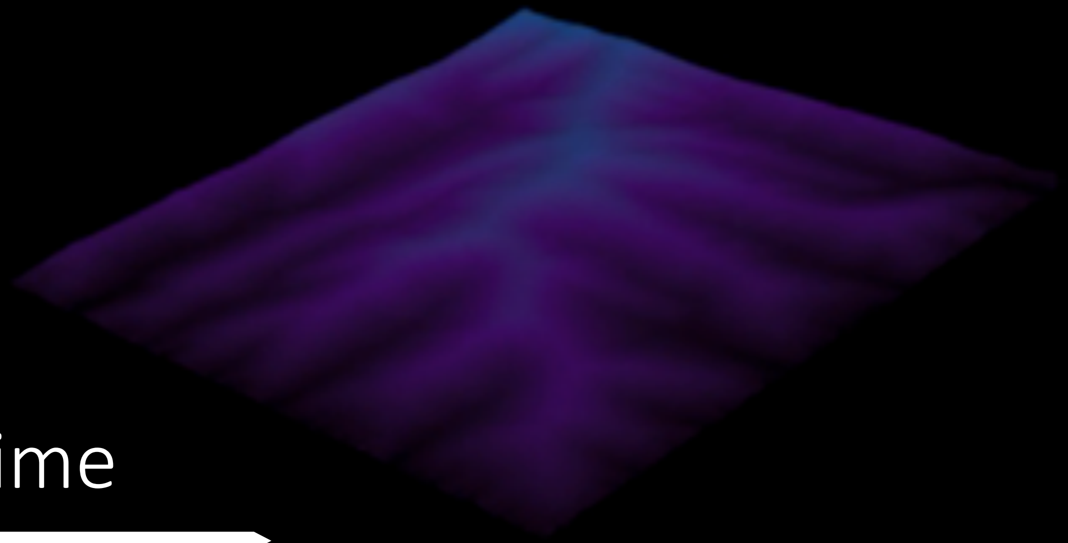


time

A fundamental landscape evolution model

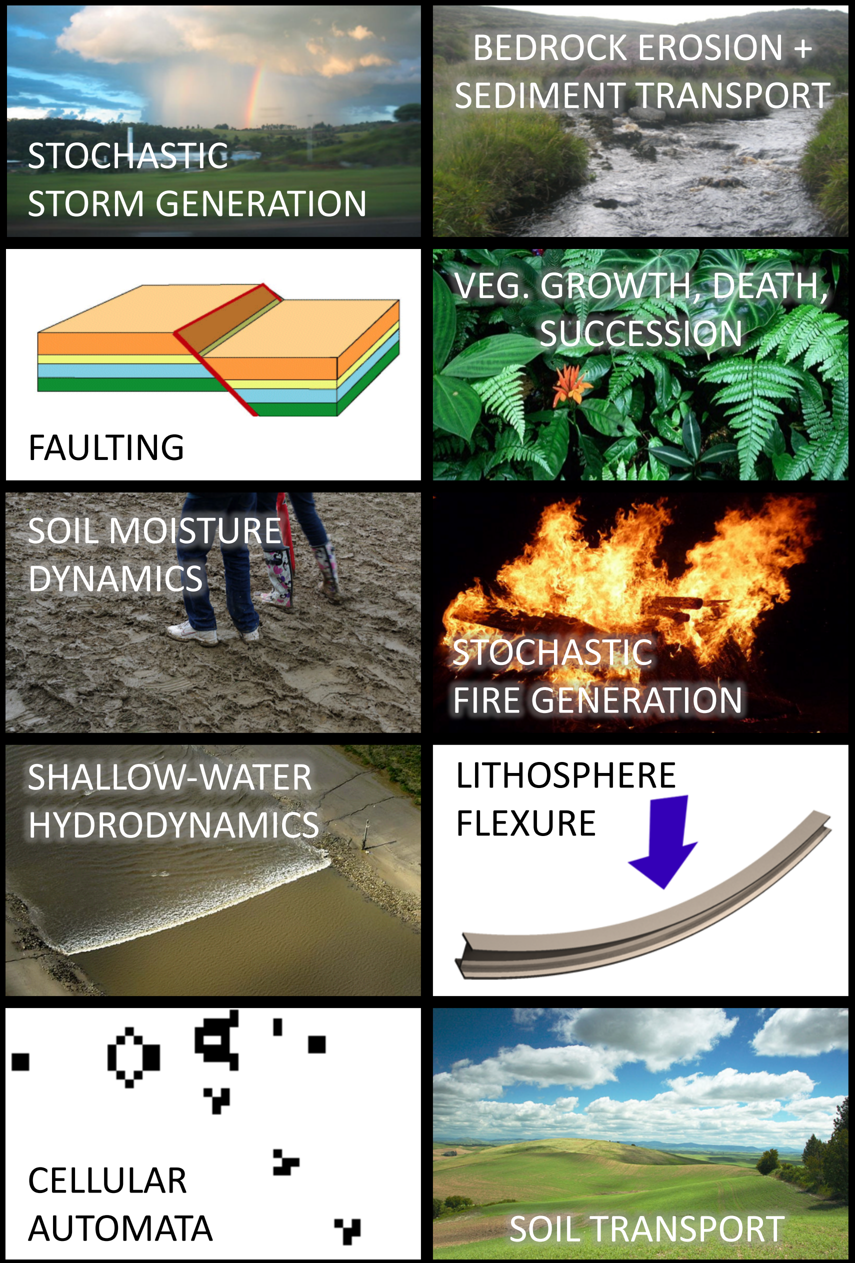
$$\partial z / \partial t = U - KA^m S^n + D\nabla^2 z$$

elevation over time = rock uplift − stream incision + hillslope diffusion



time

example Landlab components



LANDLAB surface dynamics modeling toolkit

CSDMS
community surface dynamics modeling system

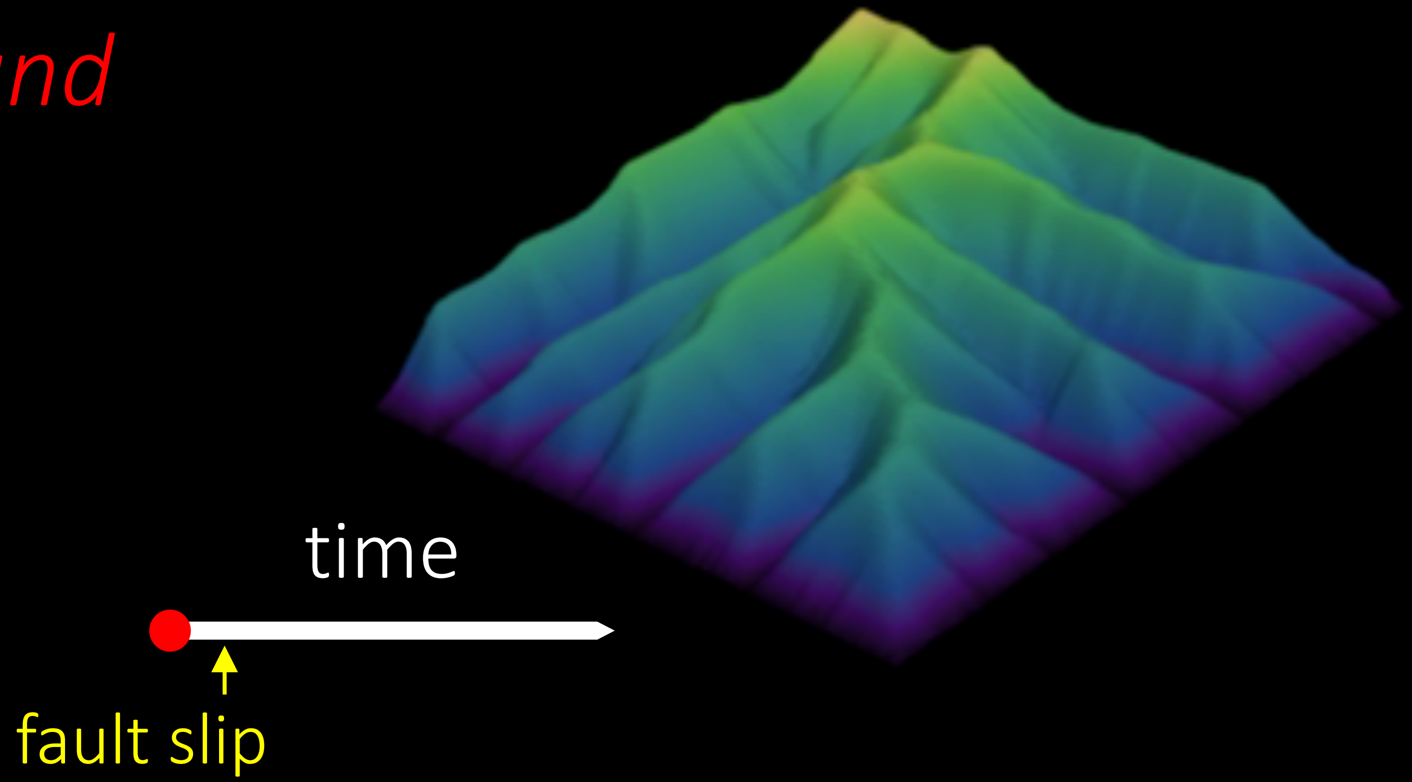
- Processes are plug & play, standardized **components**
- Landlab 2.0: Barnhart et al. 2020, Esurf

SpeciesEvolver: new component to simulate biological evolution processes (see Lyons et al. 2020, JOSS)

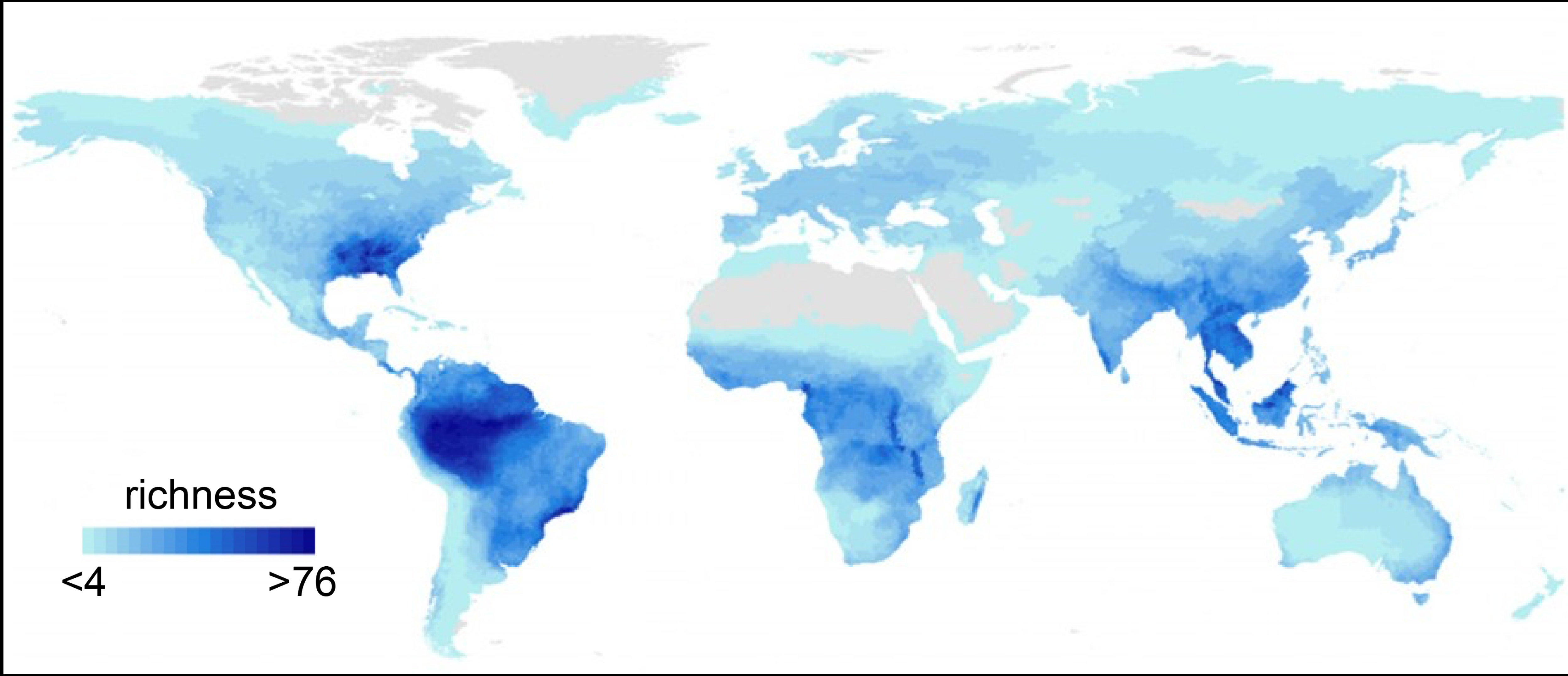
Operates at:

- geologic, macroevolution timescales
- landscape spatial scale

How can we use LEMs to advance understanding of biological evolution as it responds to climate and tectonics?



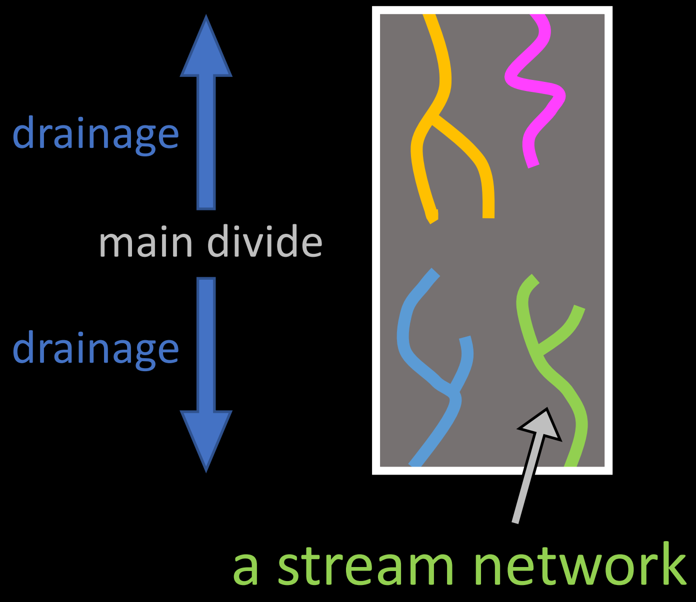
Global freshwater species richness

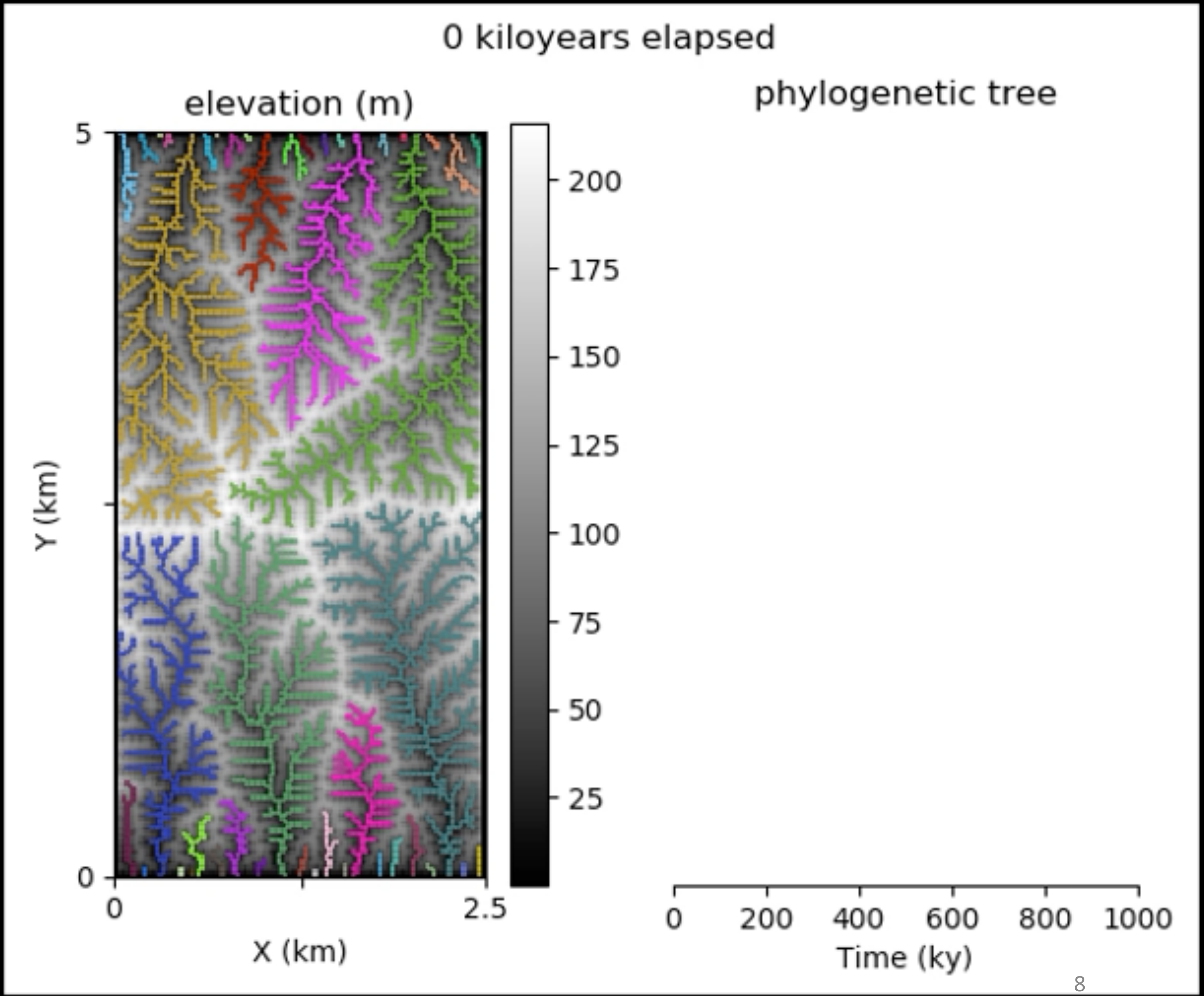


Collen et al. 2014, Global Ecol. Biogeogr.

SpeciesEvolver implemented in a landscape evolution model

Diagram of model





SpeciesEvolver implemented in a landscape evolution model

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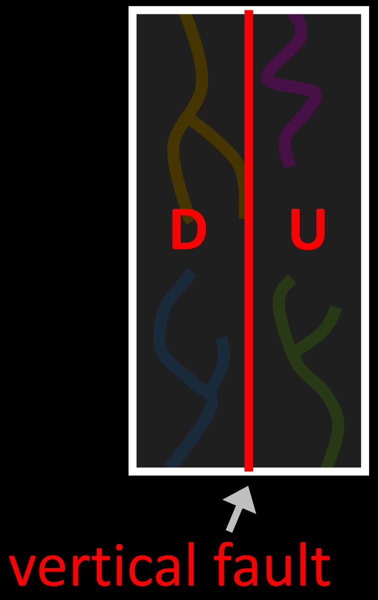
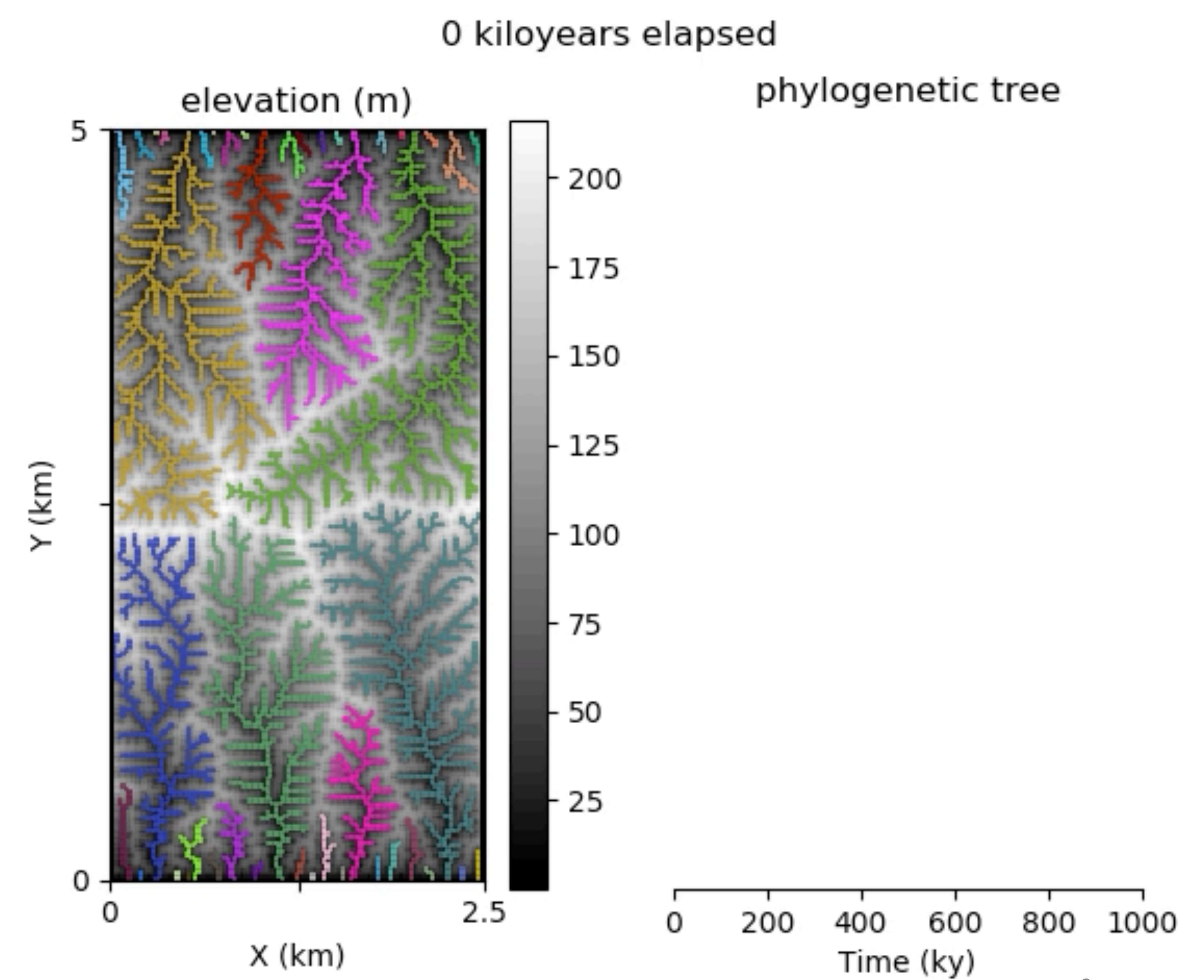
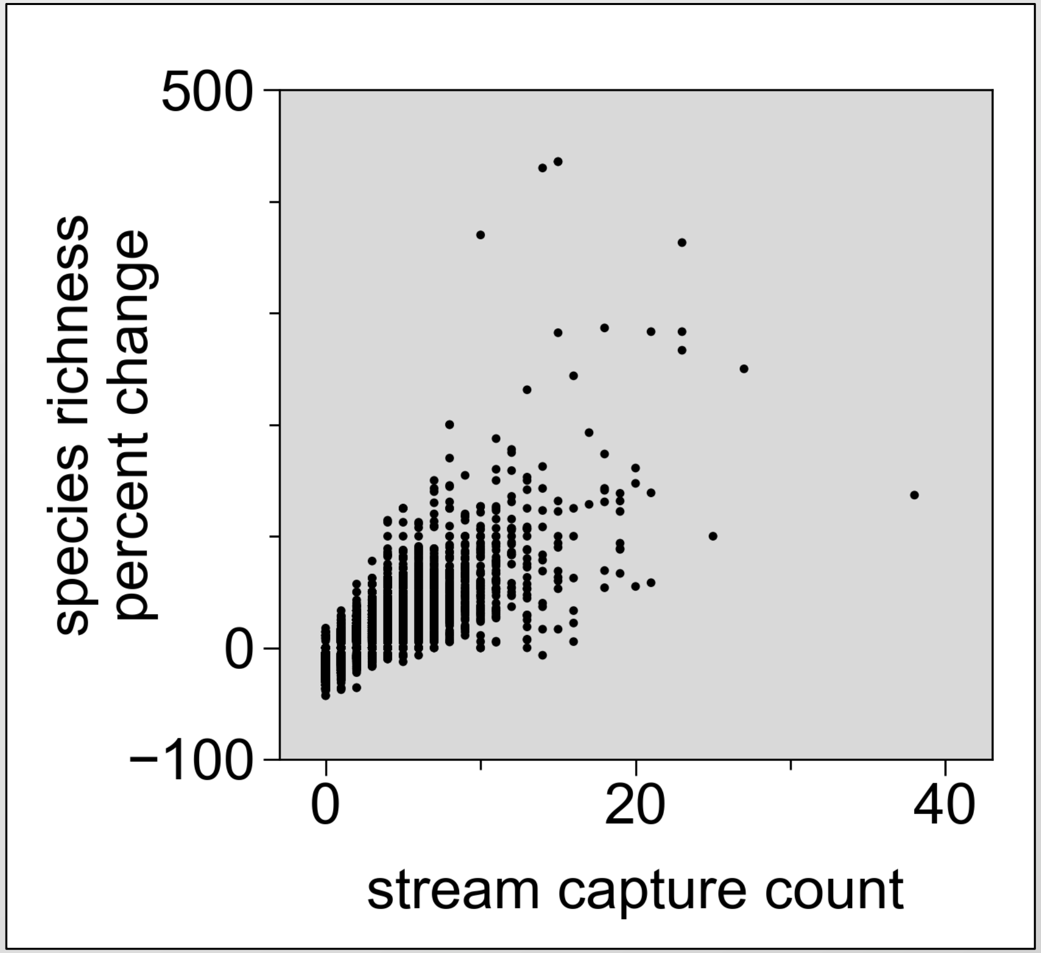
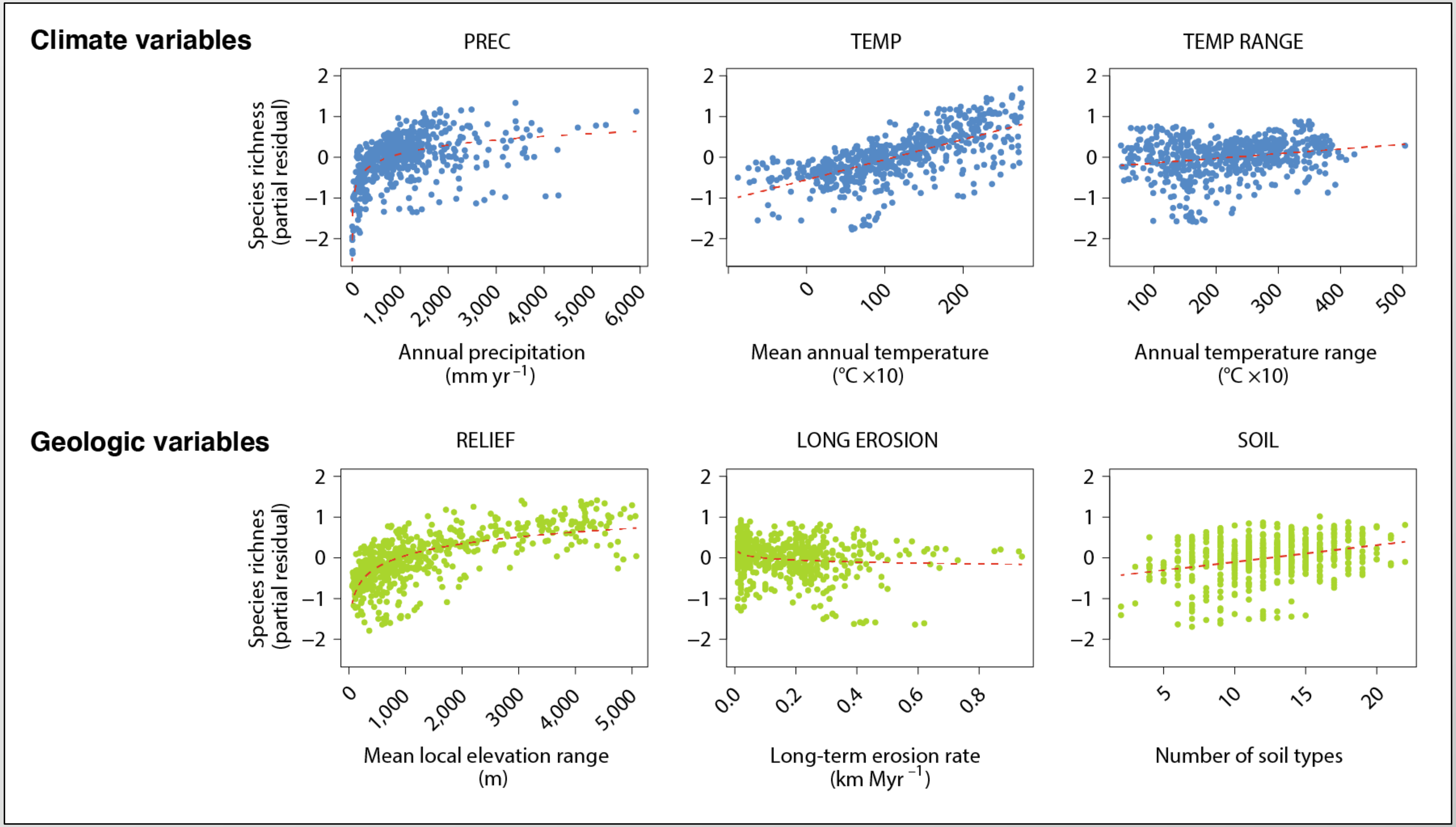




Richness as model parameters vary

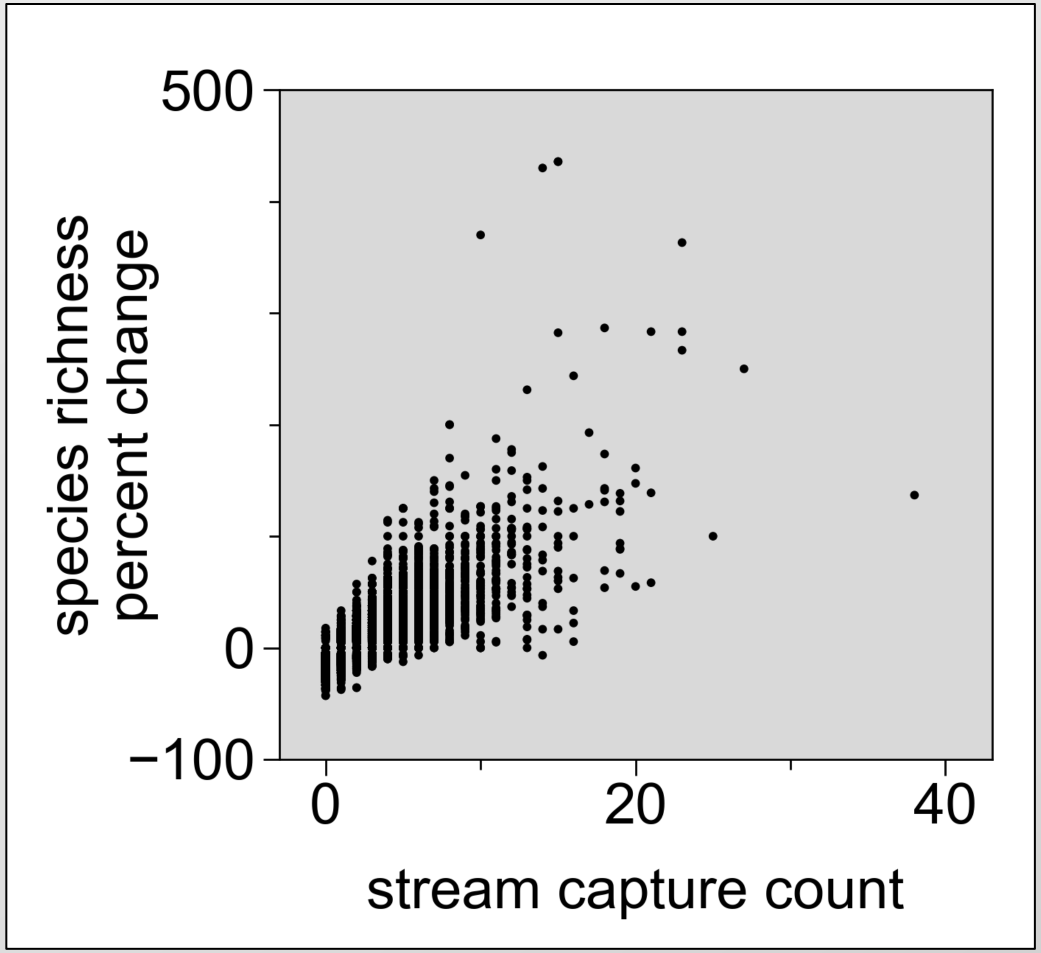


Global determinants of biodiversity across the world's mountains

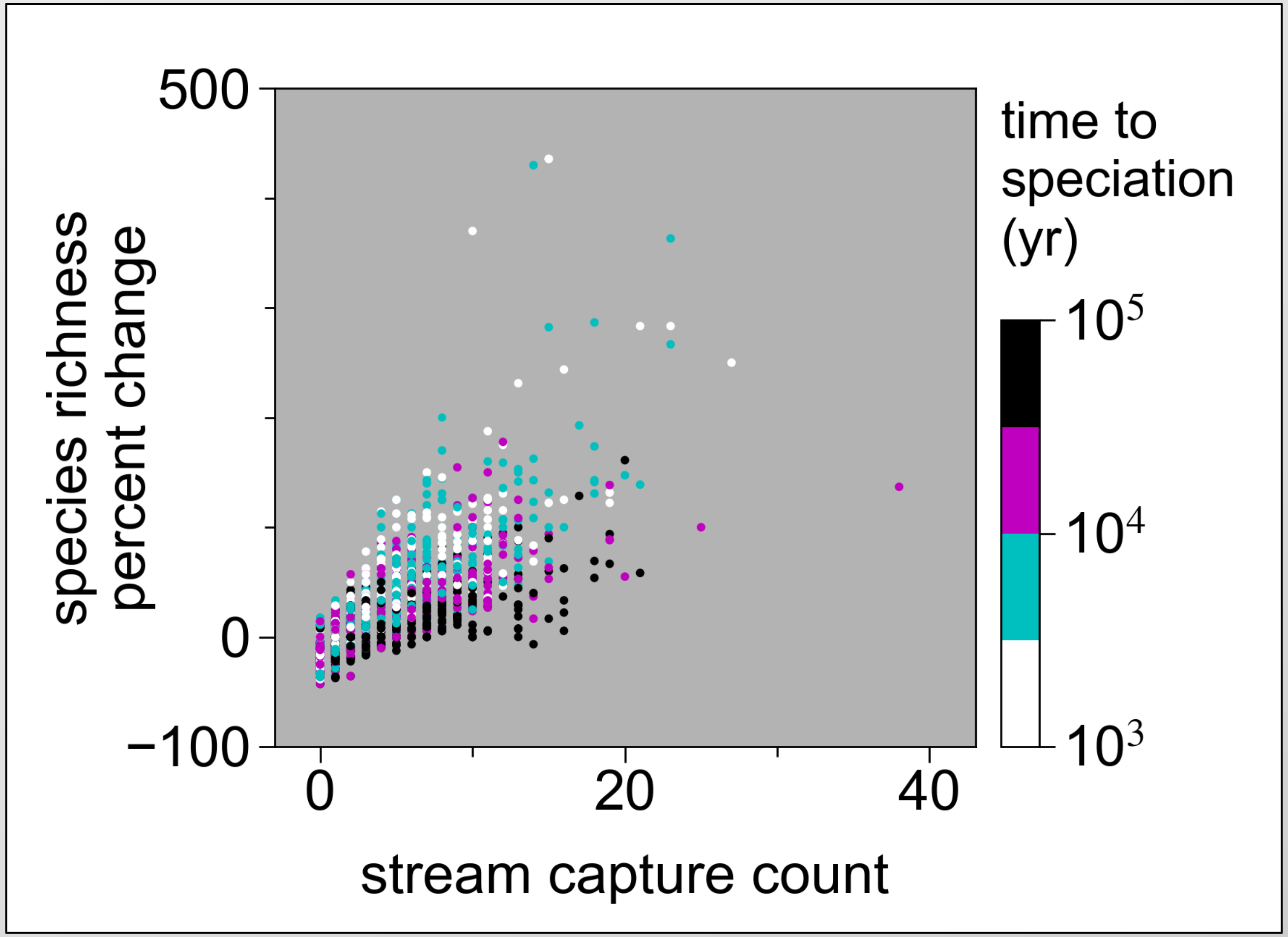


Antonelli et al. 2018, Nature Geoscience

Dynamics in the processes



Dynamics in the processes



modified from Lyons et al., 2019, ESurf

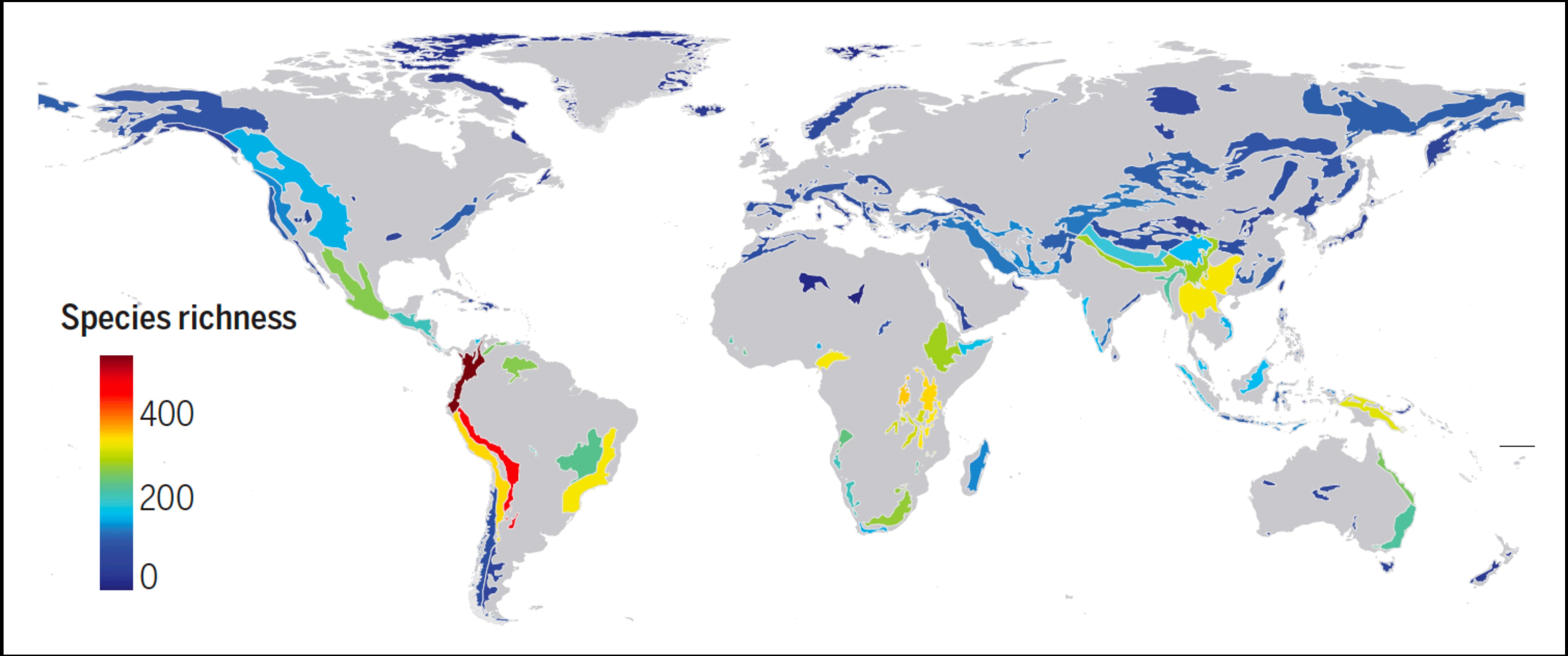
Páramos plants in the Pleistocene

Paramos are tropical montane ecosystems above the upper forest line

Foreground: Coespeletia moritziana and *Hypericum laricifolium* in flower

Photo from Flantua et al. 2019, J. of Biogeog.

Richness of montane species



Rahbek et al., 2019, Science

Paramos and climate change

Received: 30 November 2018 | Revised: 8 March 2019 | Accepted: 8 April 2019
DOI: 10.1111/jbi.13607

RESEARCH PAPER

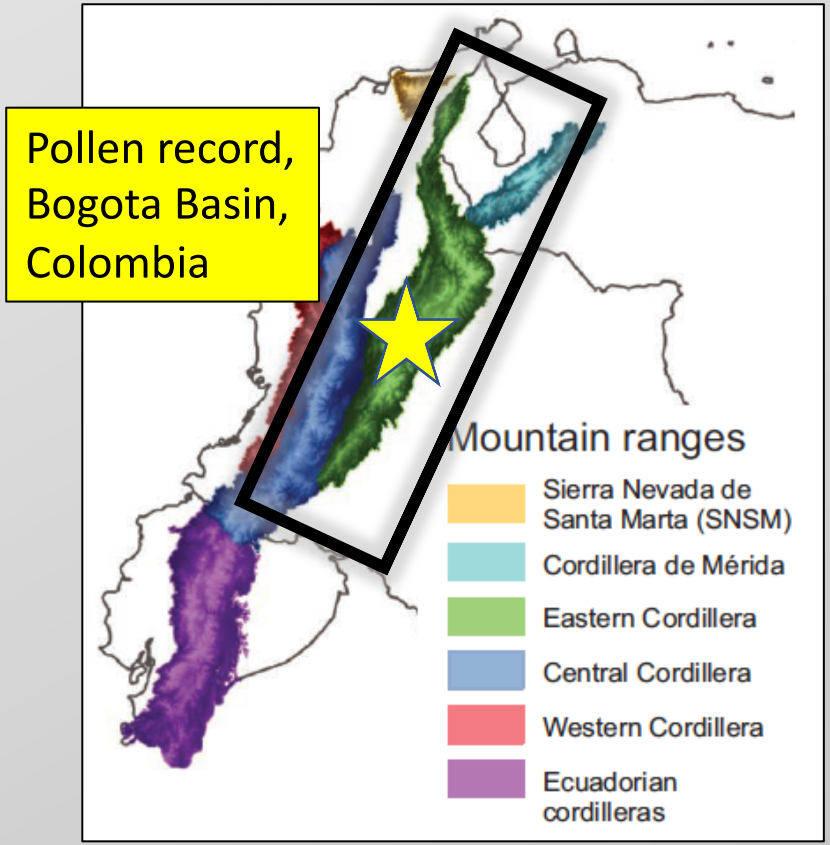
Journal of Biogeography

The flickering connectivity system of the north Andean páramos

Suzette G.A. Flantua[1,2] | Aaron O'Dea[3] | Renske E. Onstein[4] | Catalina Giraldo[1,5,6] | Henry Hooghiemstra[1]

Prior research

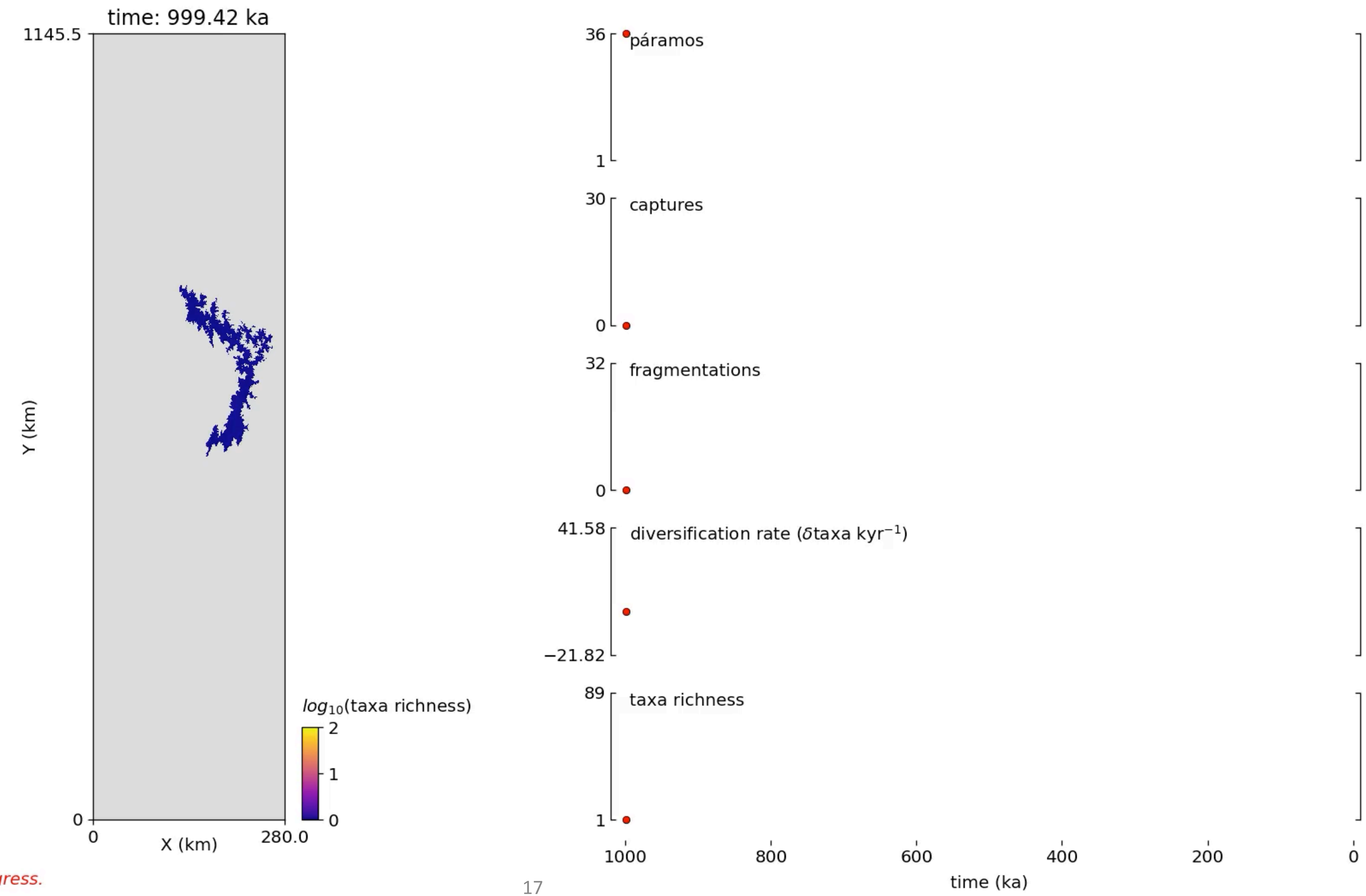
Mapped extent of paramos in northern Andes over past 1 ma



Flantua et al. (2019)

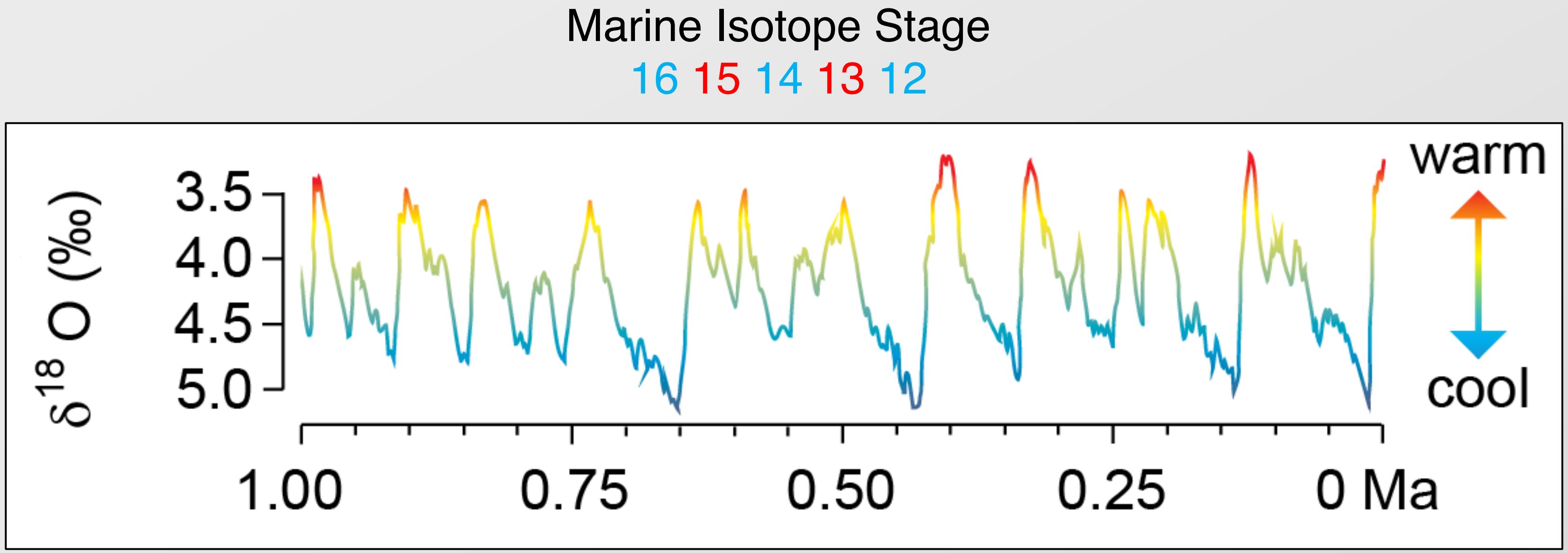
New application of SpeciesEvolver

- Paramos of the Eastern Cordillera
- Evolves by dispersal, speciation, and extinction
- Overall fitness tuned to paramo area

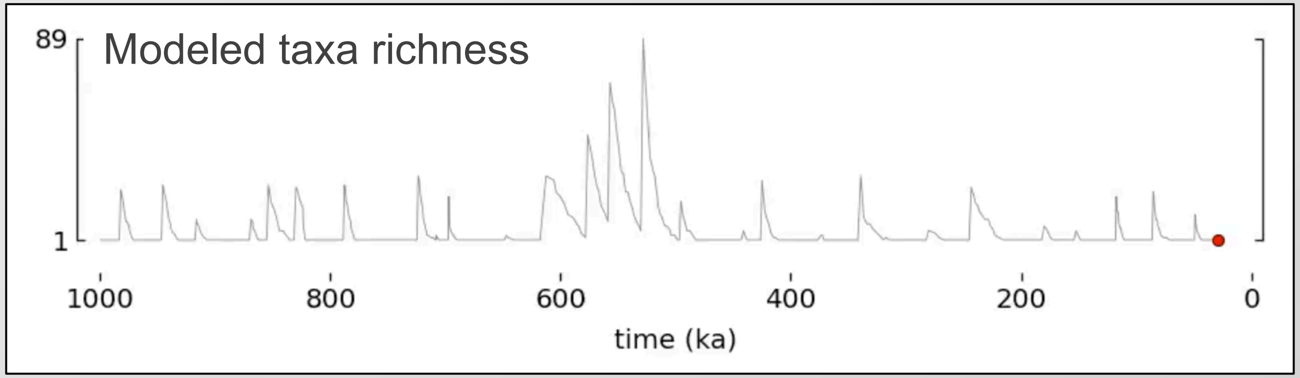


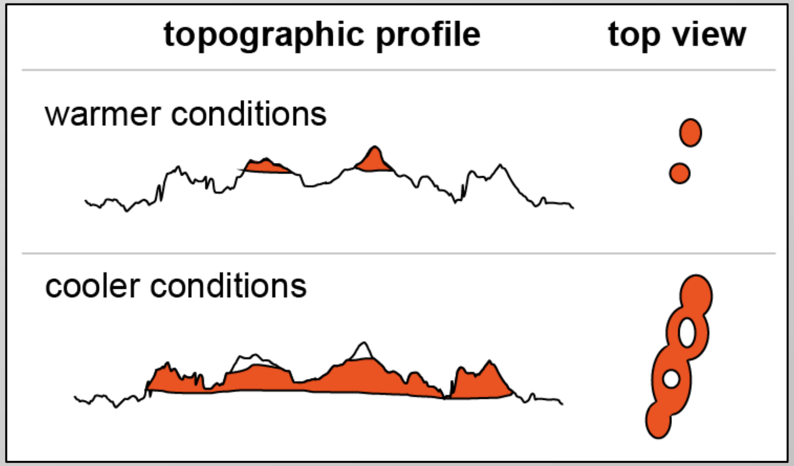
Lyons and Flantua, in progress.

Simulated richness and Pleistocene climate fluctuations



Lisiecki & Raymo, 2005, Paleoceanography





Flantua et al. (2019)

"***Nothing in biology makes sense except in the light of evolution***"

- Theodosius Dobzhansky

"***Very little in evolution makes sense except in the light of genetics***"

- Jody Hey

Key points

Integrating genetics in **LEMs** will

- better represent complexity
- improve comparison between empirical & model data

LEMs support process-based research into biological evolution

LEMs = Landscape evolution models

Acknowledgements

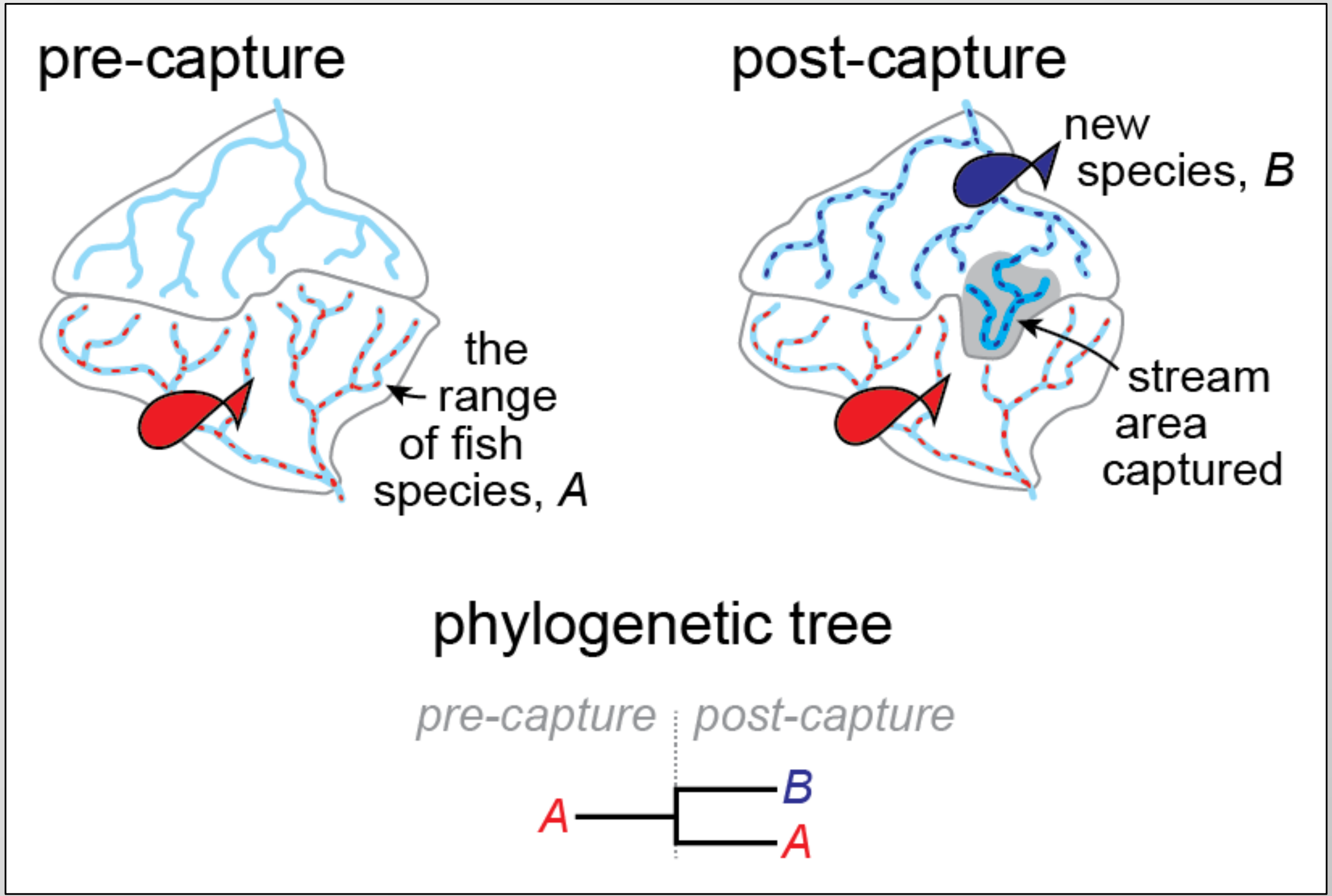
Support from the National Science Foundation and CRDF Global.

Technical assistance and computational resources from CSDMS and Tulane's HPC center.

Supplemental slides

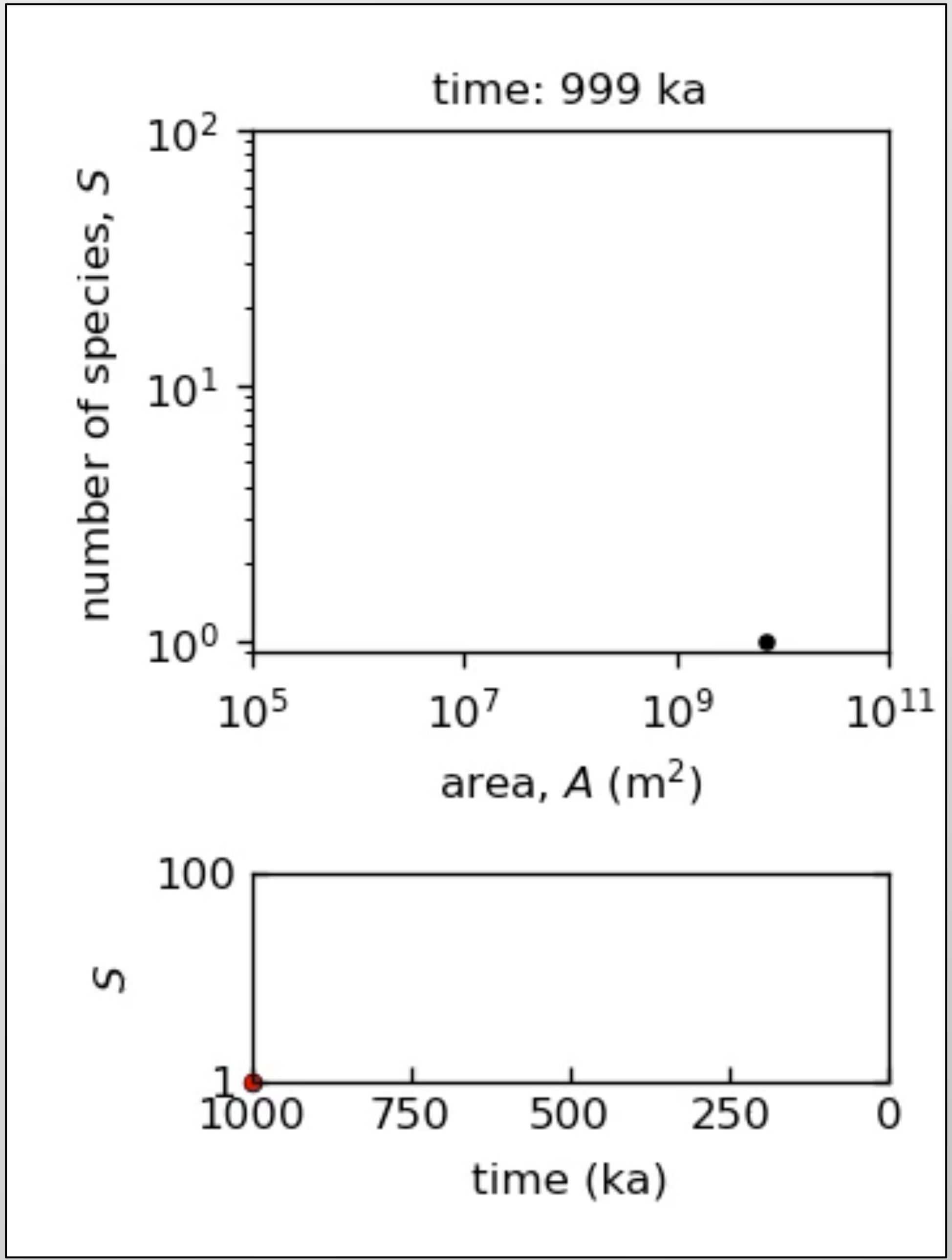
Speciation in SpeciesEvolver

- Triggered by geographic range fragmentation (allopatric speciation)
- Other speciation mechanisms and details readily configurable



Area-species relationship

Plants in the Pleistocene



Drainage reorganization and fish