Deconstructing diversity
starting out, getting there, staying alive




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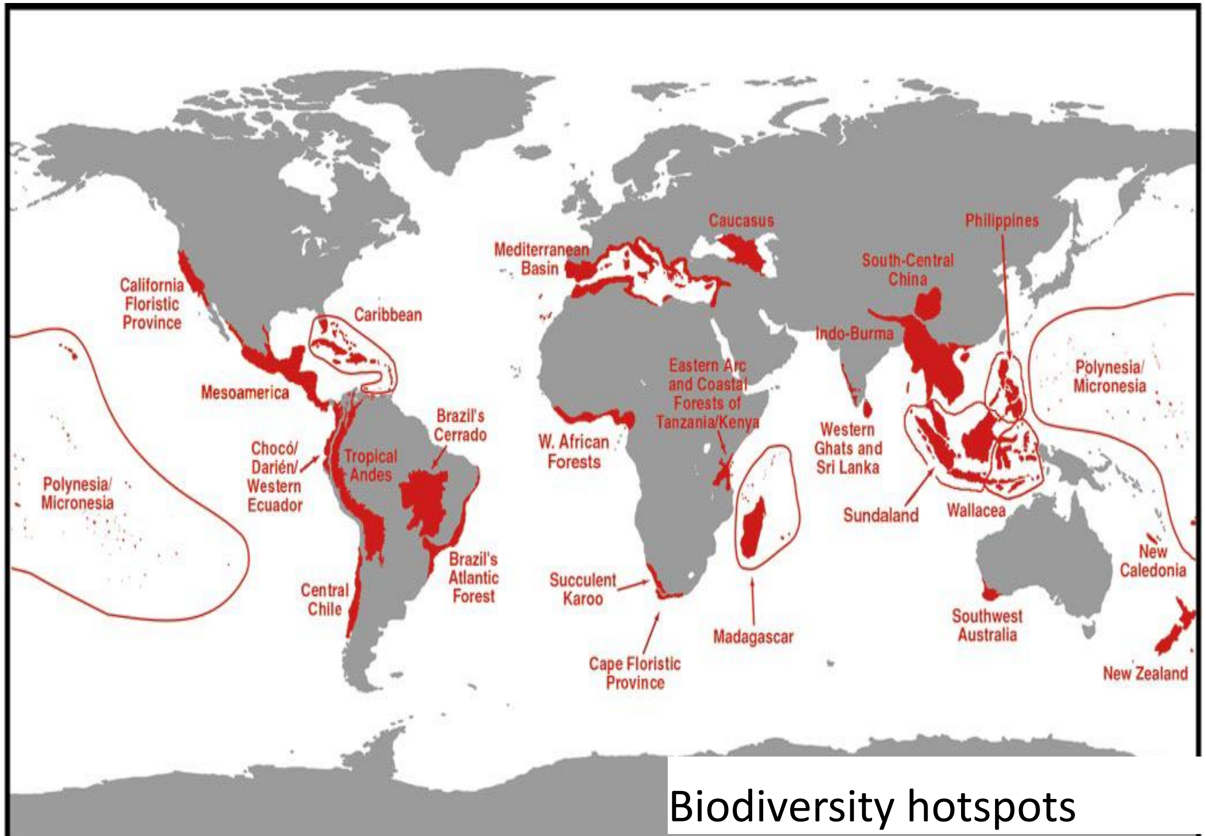
What causes diversity ?

Why do some areas within the tropics have greater diversity?



Wiens 2011 Cracraft 1985

Map: Conservation International

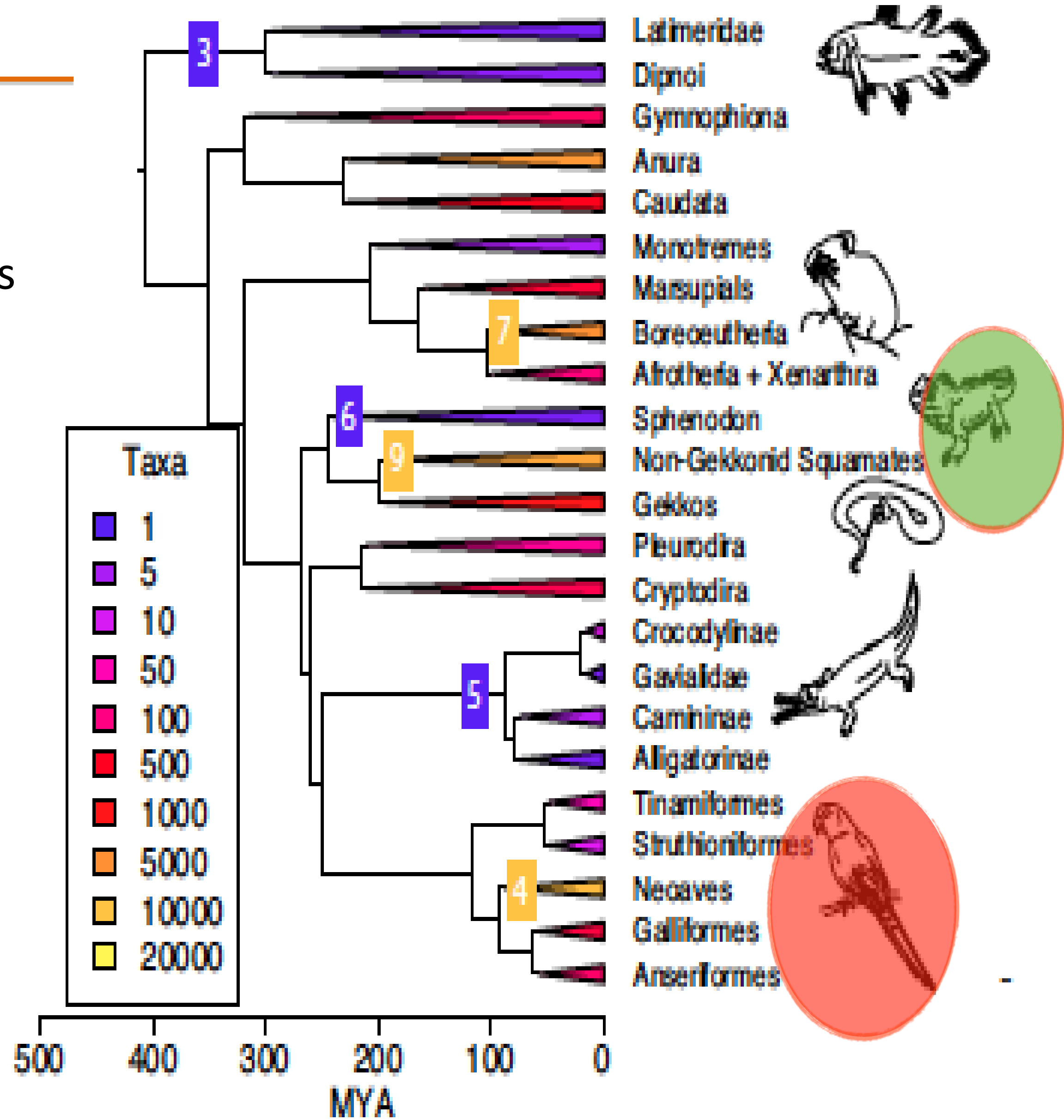
Diversity in clades

Clade - group composed of ancestor and all its descendants

Why is the diversity of some clades greater?

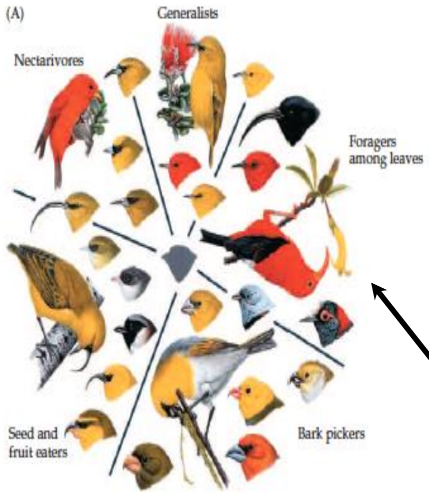
> 200 million years old
& 2 species

Image:http://reptilis.net

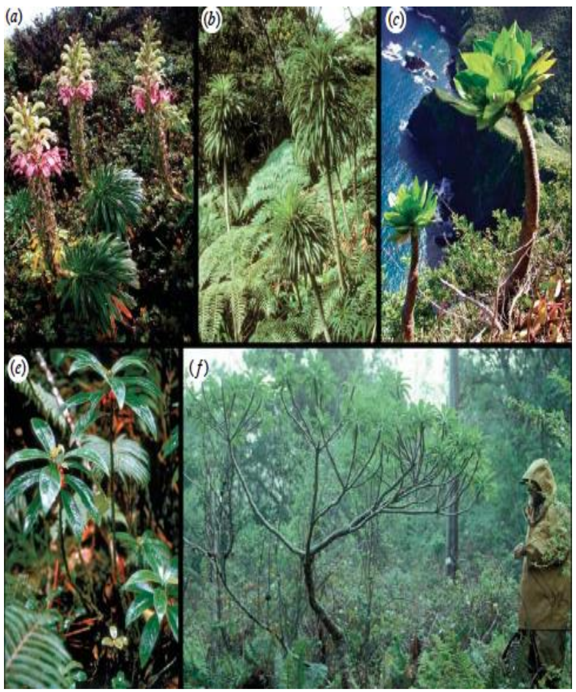


Alfaro et al. 2009

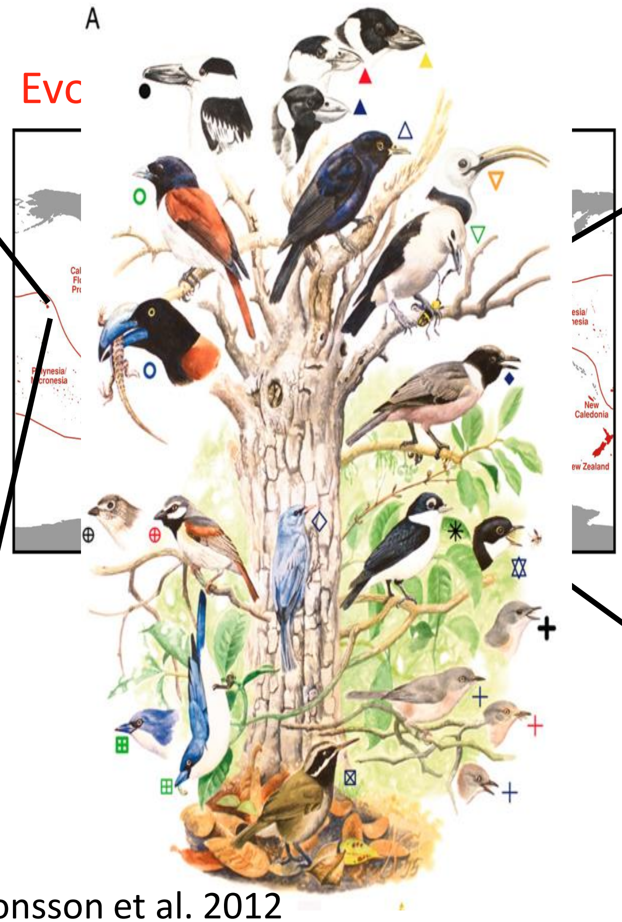
Diversity in time and space



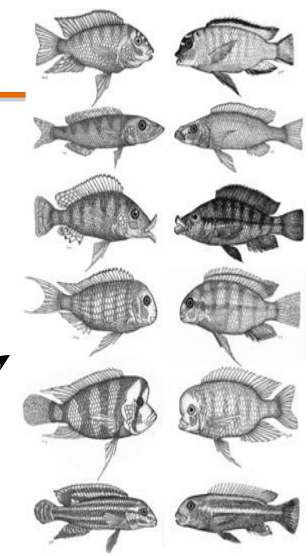
Pratt 2005



Givnish 2010



Jonsson et al. 2012



Seehaunsen 2006

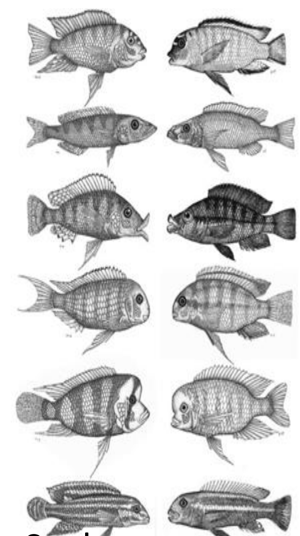
Losos 2009

Connecting diversity in space and in radiations

Pratt 2005

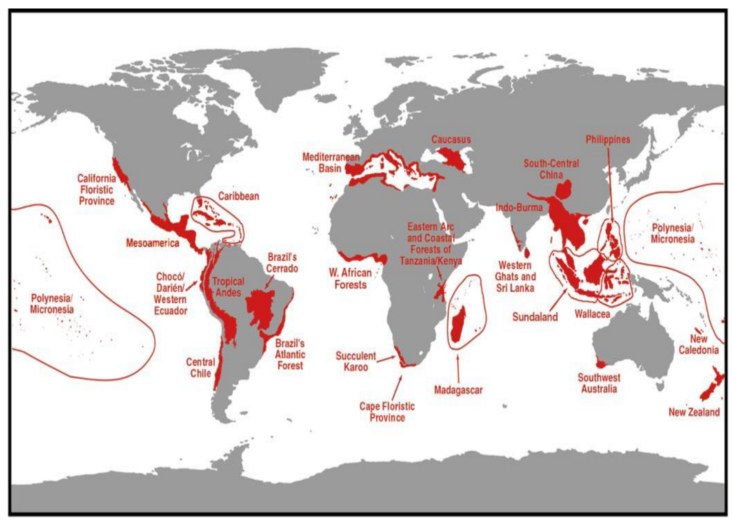
Diversity in space/hotspot =

Summation of patterns among clades
+
biogeographic processes (dispersal)



Seehaunsen 2006

Givnish 2010



Cracraft 1985

Losos 2009

Todays talk: diversification in the Western Ghats

- An evolutionary biogeography perspective of diversity

- Starting out: an evolutionary perspective

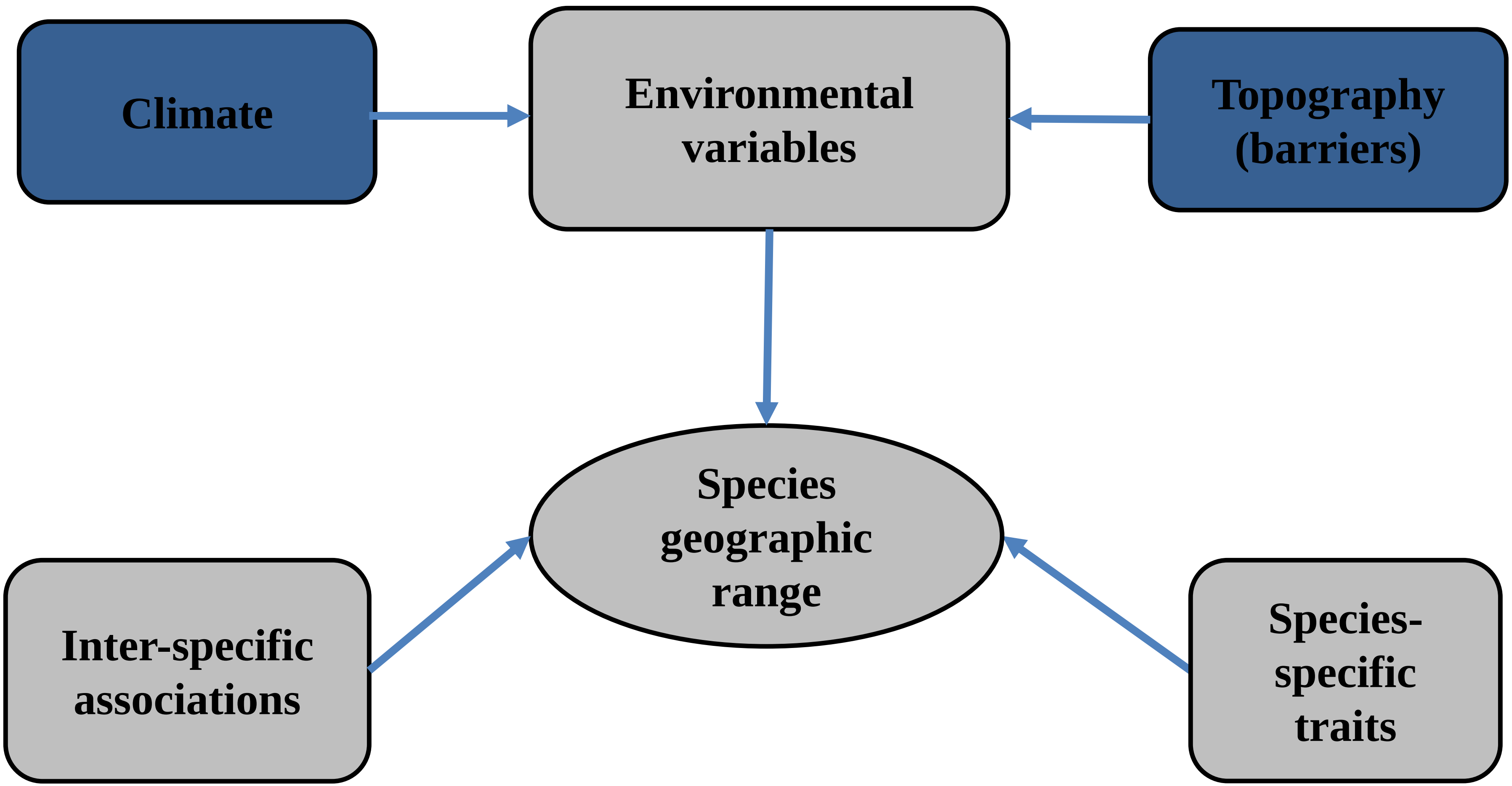
  - The challenge of delimitation
  - Understanding evolutionary origins

- Getting there and staying alive: a macroecological view

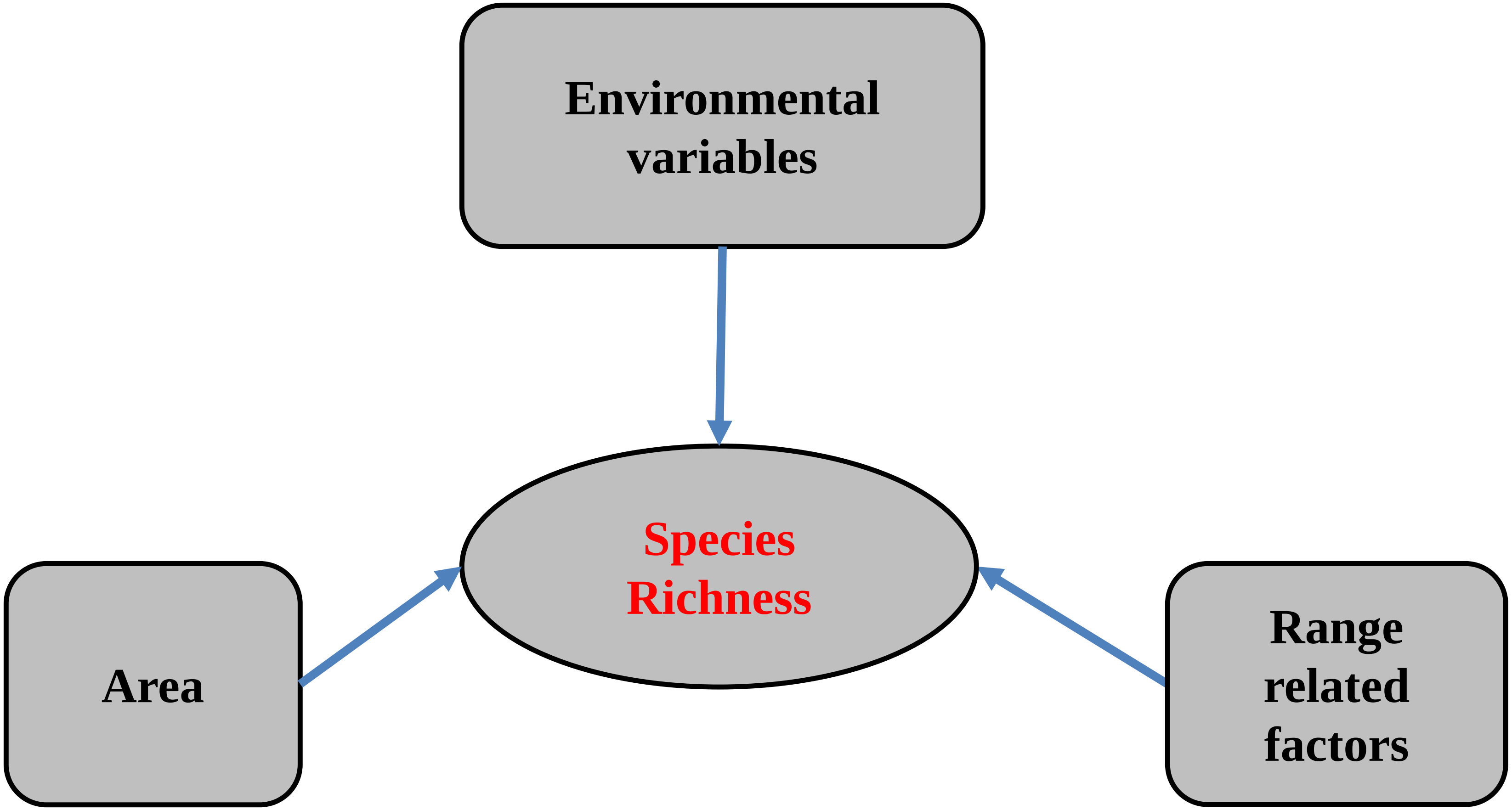
  - Staying alive: factors influencing persistence
  - Getting there: the role of dispersal
  - Combining environment and range

- The road from distribution to diversity: a brief synthesis

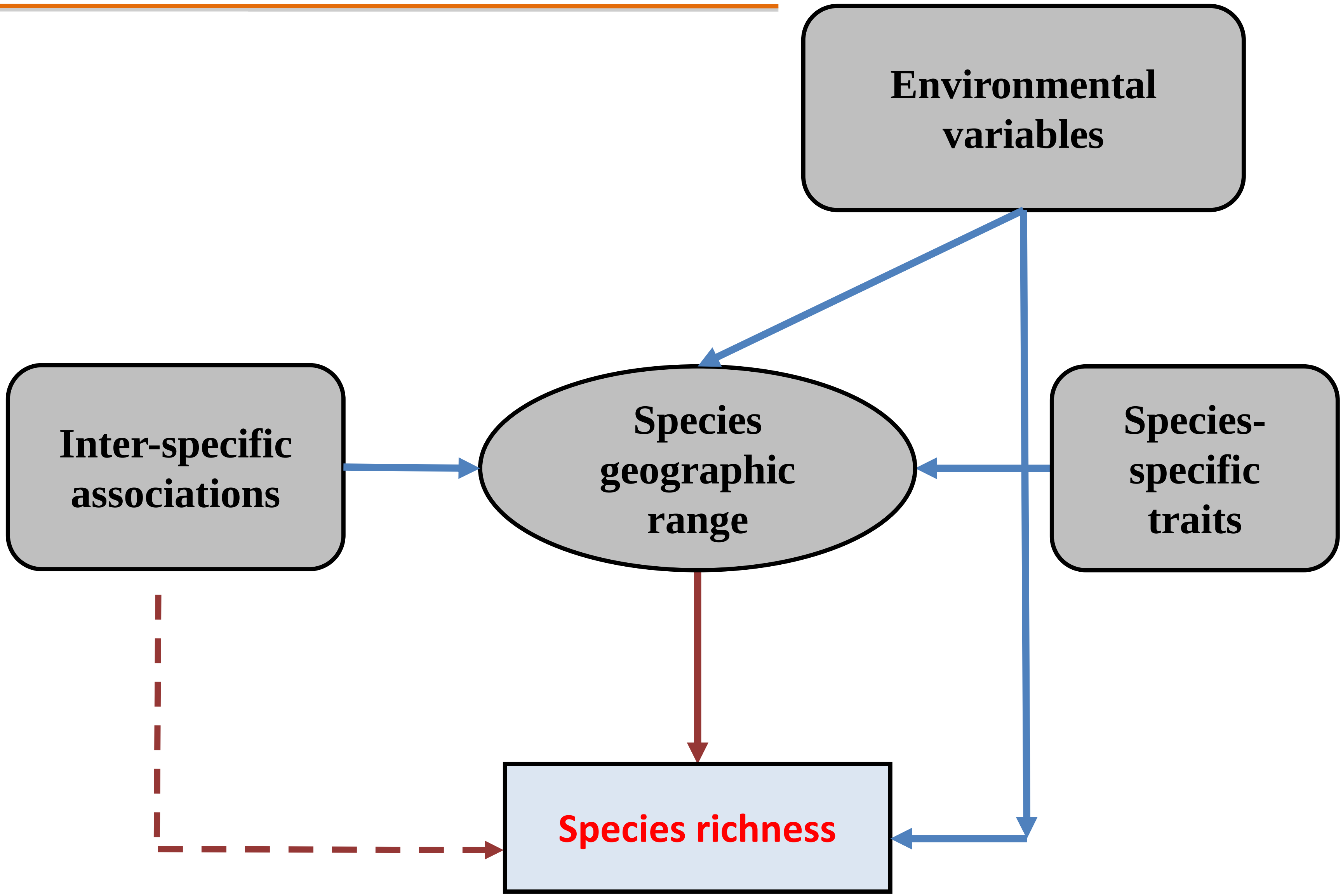
Determinants of species range



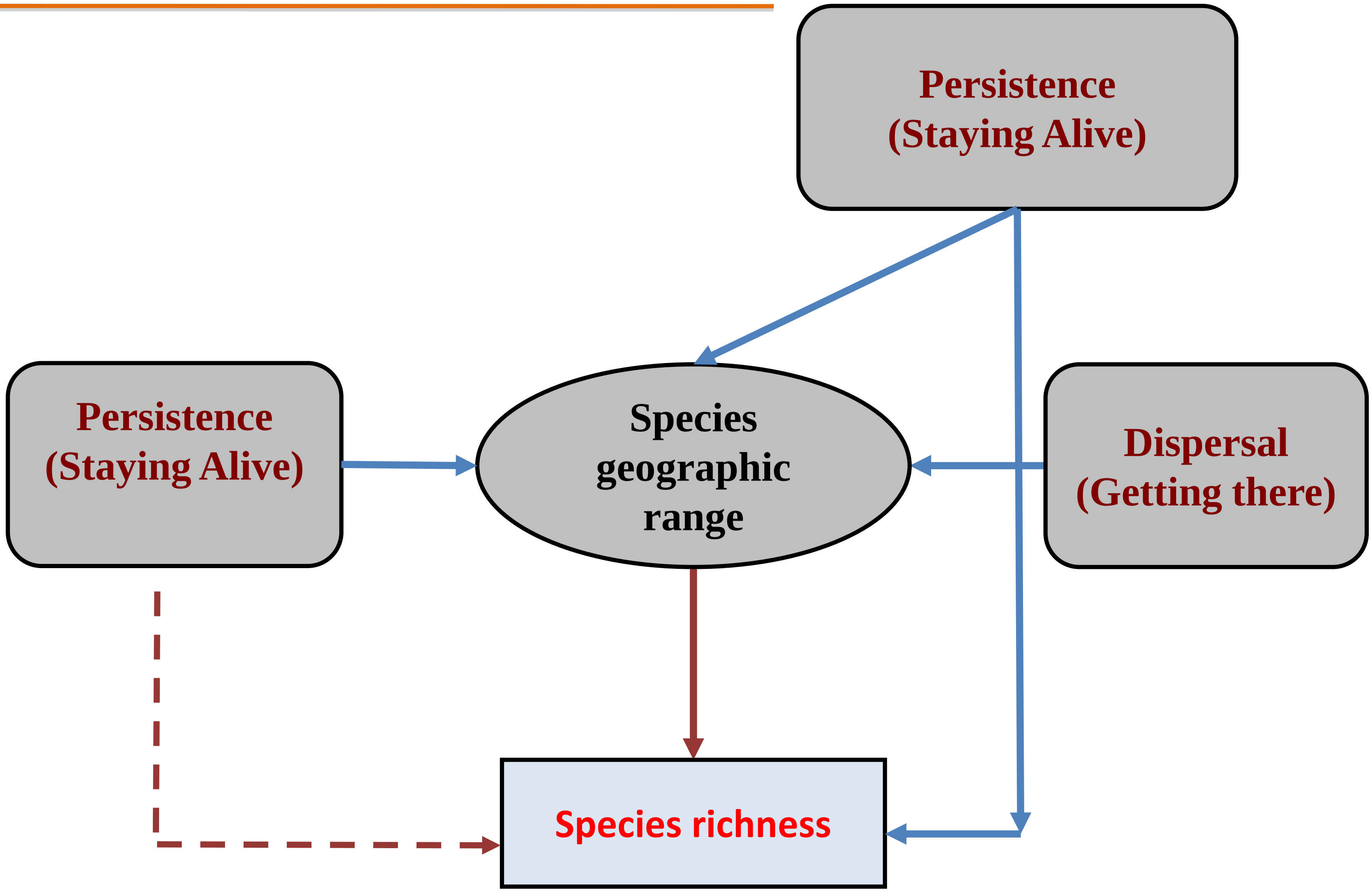
Determinants of species richness



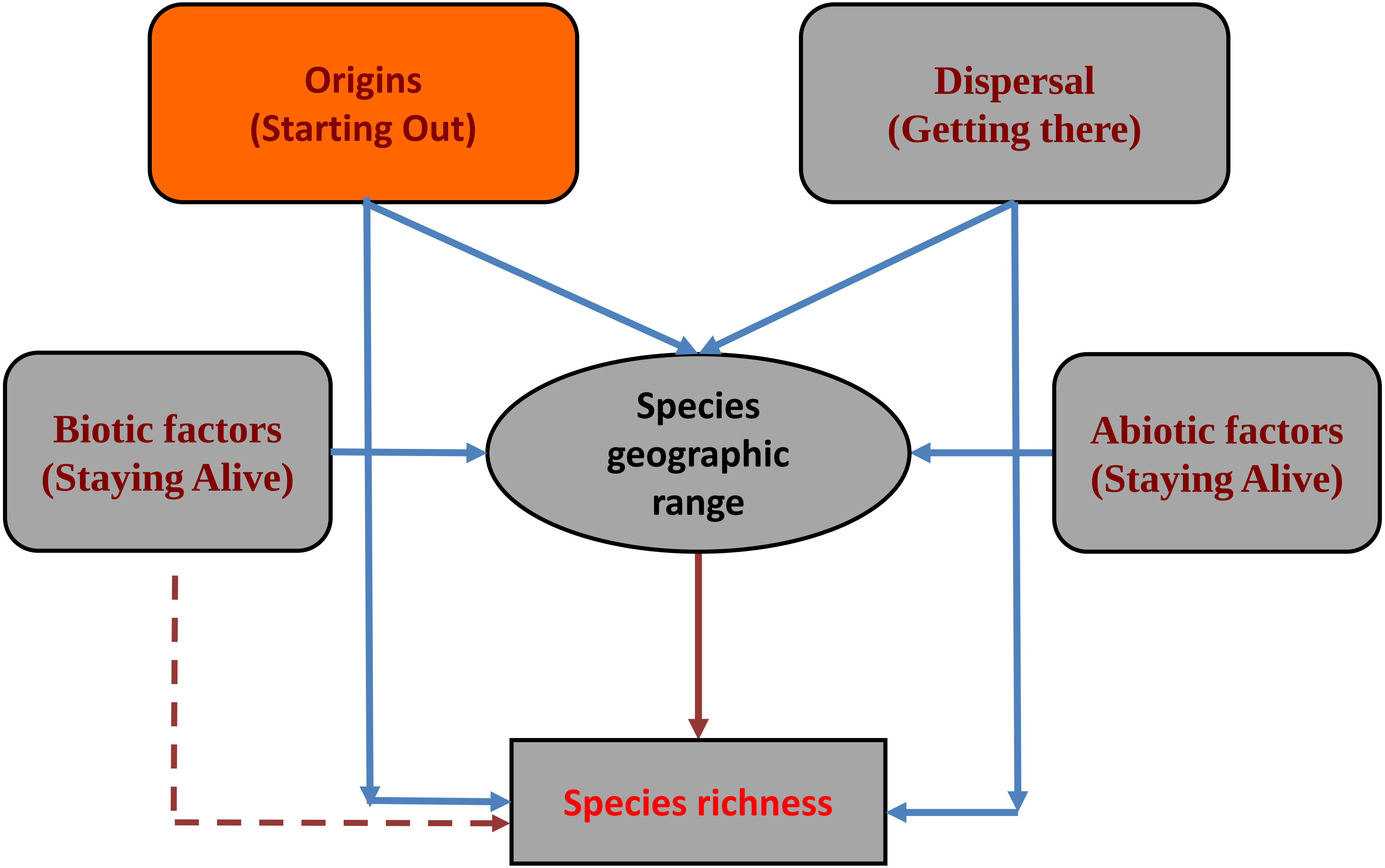
General conceptual framework

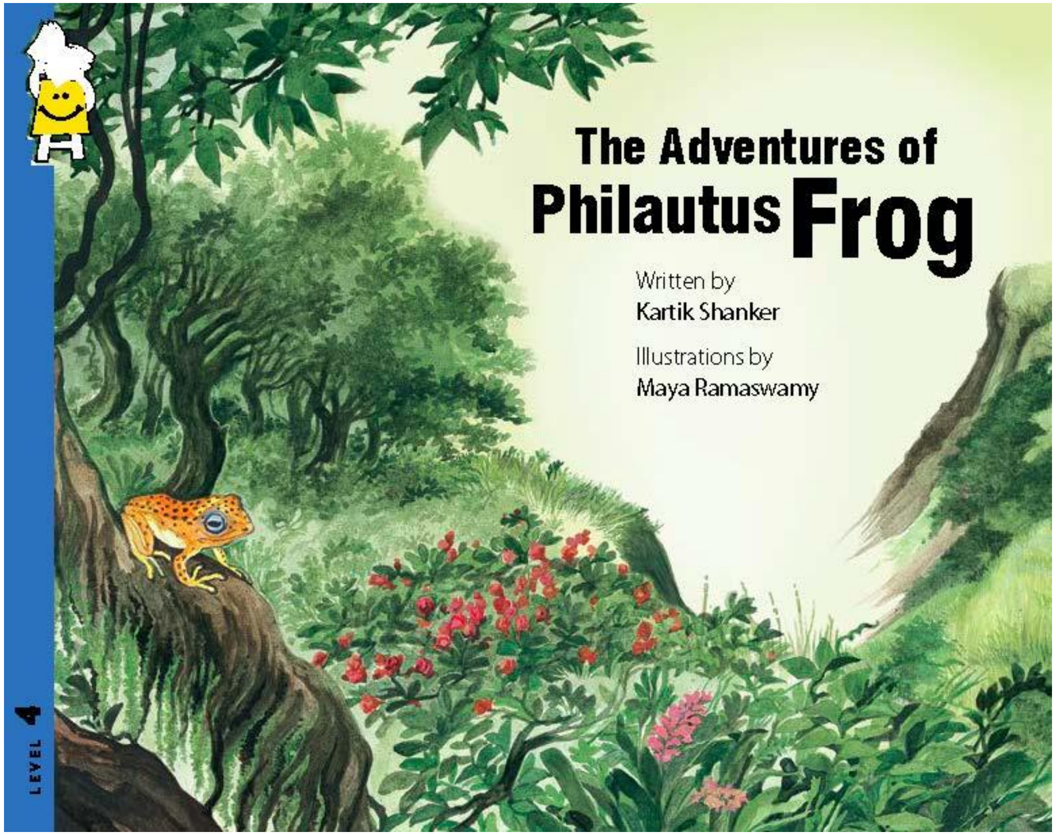


General conceptual framework



Synthetic framework



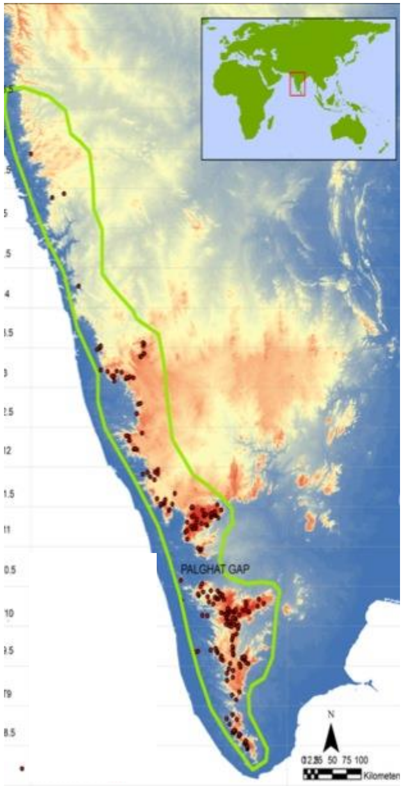

The Adventures of
Philautus Frog
Written by
Kartik Shanker
Illustrations by
Maya Ramaswamy
LEVEL 4

Two detective stories

The Linnaean shortfall
The Wallacean shortfall

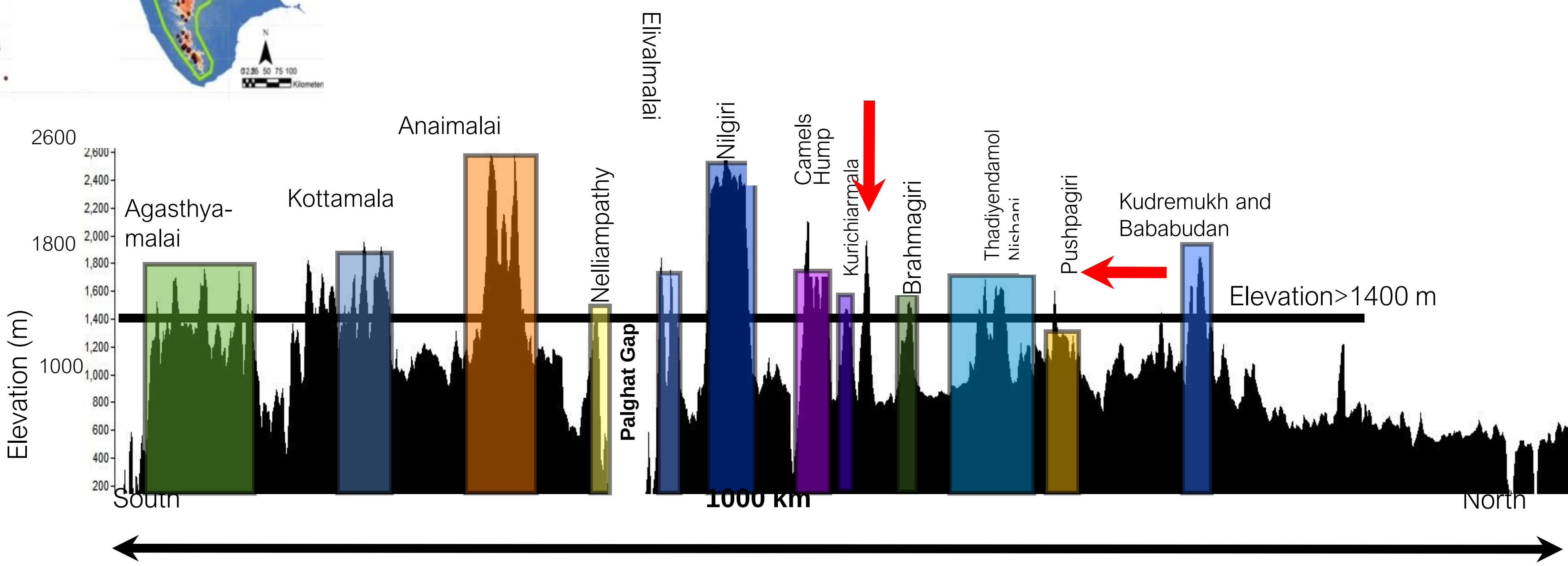
Bush frogs - *Raorchestes*

Wrinkled frogs - *Nyctibatrachus*

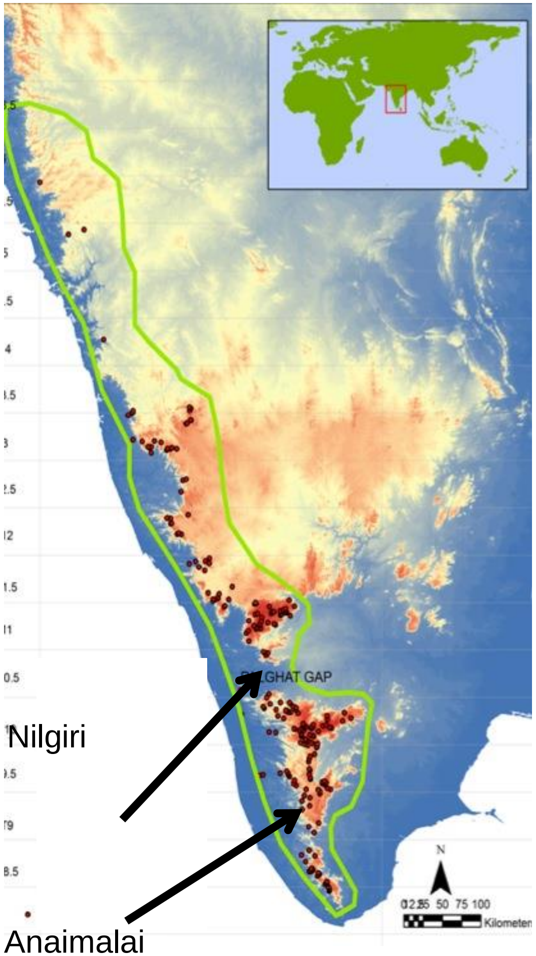


Large scale sampling framework

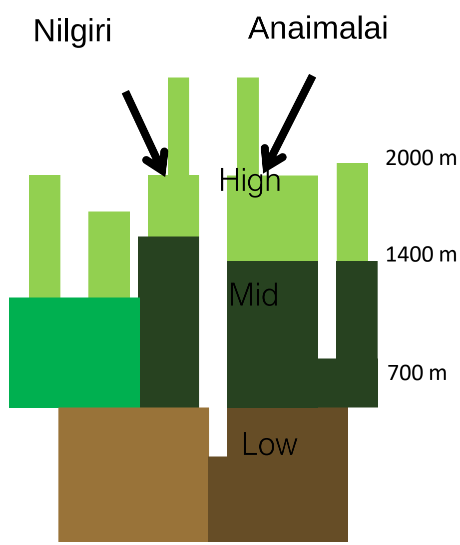
- Capture topographic, bioclimatic and geological heterogeneity
- Massifs - elevational range from 0 to 2650m
- Delimited 14 mountain complexes >1400m
- Sampled most of the massifs (over a 5 year period)
- Across available elevational gradients



Site selection and sampling methods



Across broad elevational bands (vegetation based)



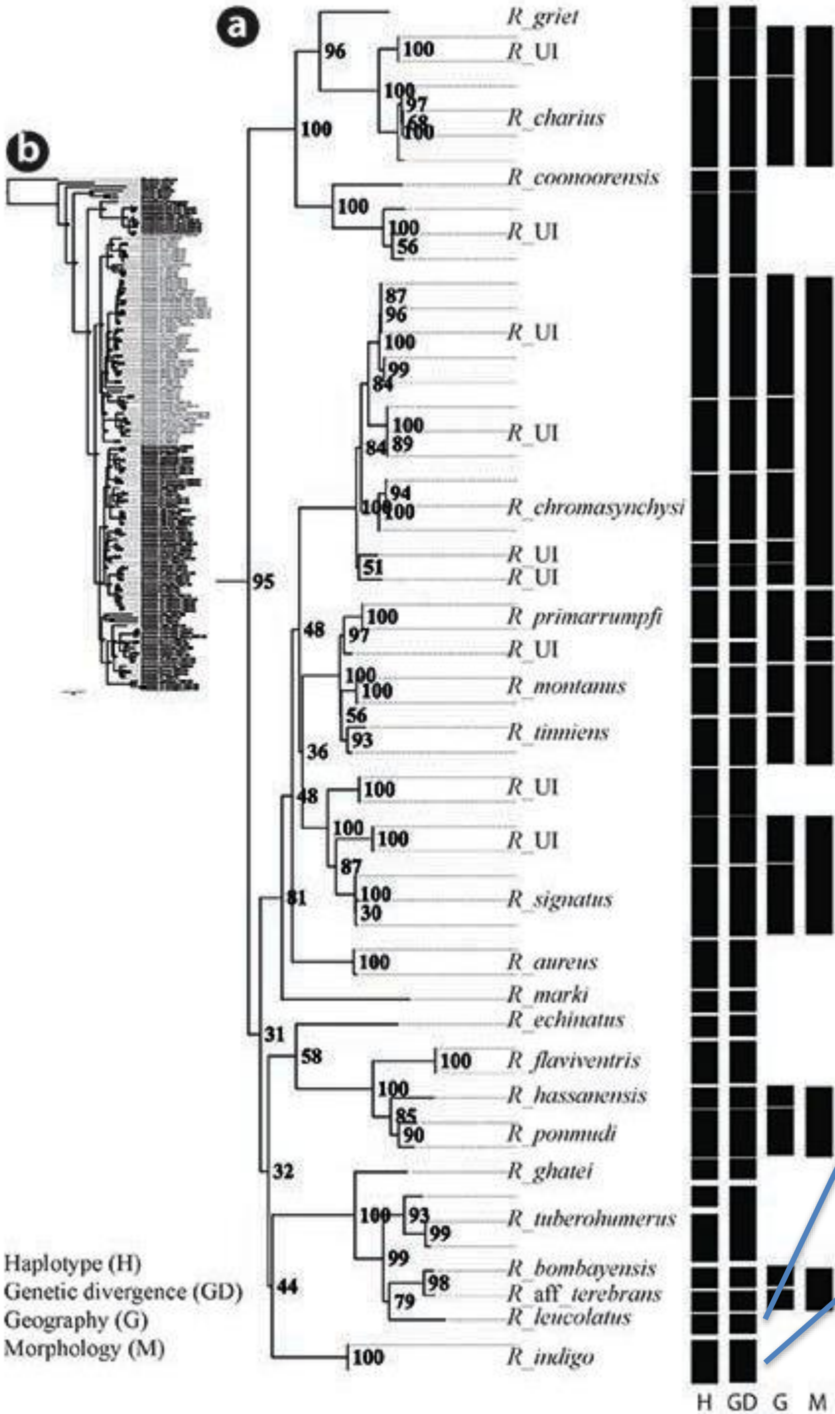
No. of sites = 250
No. of points = 20,000
Elevational range =100 - 2650m

Lineage delimitation : A step wise multi-criteria approach

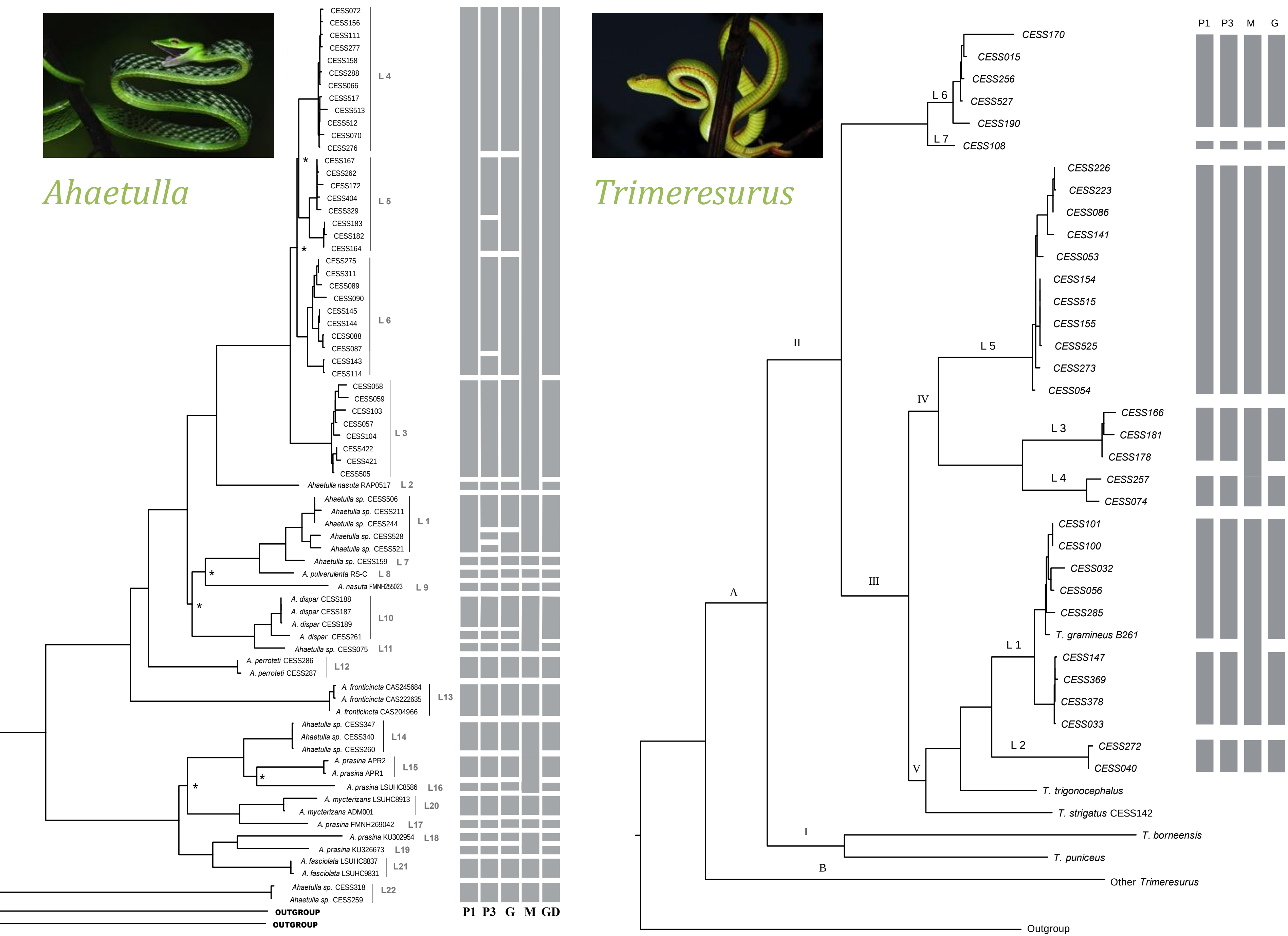
Step 1: Haplotype phylogeny: ML Tree
Step 2: Bayesian Poisson Tree process
Step 3: Pairwise genetic distance
Step 4: Geographic range overlap
Step 5: Morphological distinctness

- Combination of genetics, geography and morphology.
- ML Tree serves as input for bPTP which estimates the number of putative lineages.
- Each lineage is then treated as a hypothesis and evaluated using pairwise genetic distance, geographical overlap and morphology.
- Sister lineages with ‘high’ divergence treated as independent lineages/species
- Remaining pairs examined for morphological distinctness or geographical separation

Raorchestes

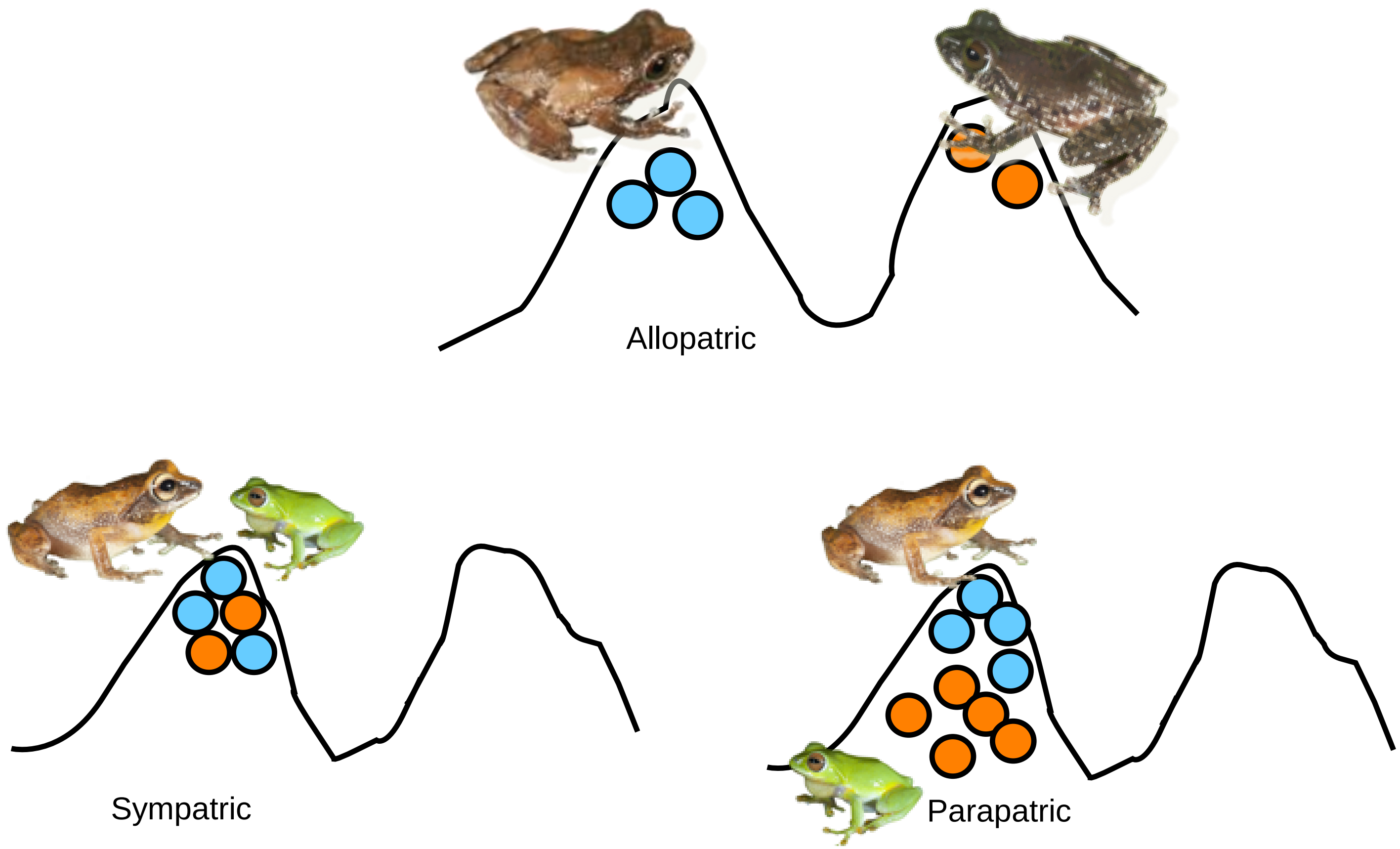


Nyctibatrachus

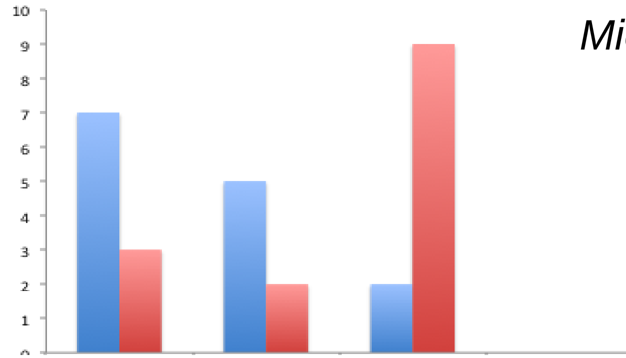


Ahaetulla
CESS072
CESS156
CESS111
CESS277
CESS158
CESS288
CESS066
CESS517
CESS513
CESS512
CESS070
CESS276
L 4
CESS167
CESS262
CESS172
CESS404
CESS329
CESS183
CESS182
CESS164
L 5
CESS275
CESS311
CESS089
CESS090
CESS145
CESS144
CESS088
CESS087
CESS143
CESS114
L 6
CESS058
CESS059
CESS103
CESS057
CESS104
CESS422
CESS421
CESS505
L 3
Ahaetulla nasuta RAP0517
L 2
Ahaetulla sp. CESS506
Ahaetulla sp. CESS211
Ahaetulla sp. CESS244
Ahaetulla sp. CESS528
Ahaetulla sp. CESS521
L 1
Ahaetulla sp. CESS159
L 7
A. pulverulenta RS-C
L 8
A. nasuta FMNH255023
L 9
A. dispar CESS188
A. dispar CESS187
A. dispar CESS189
A. dispar CESS261
L10
Ahaetulla sp. CESS075
L11
A. perroteti CESS286
A. perroteti CESS287
L12
A. fronticincta CAS245684
A. fronticincta CAS222635
A. fronticincta CAS204966
L13
Ahaetulla sp. CESS347
Ahaetulla sp. CESS340
Ahaetulla sp. CESS260
L14
A. prasina APR2
A. prasina APR1
L15
A. prasina LSUHC8586
L16
A. mycterizans LSUHC8913
A. mycterizans ADM001
L20
A. prasina FMNH269042
L17
A. prasina KU302954
L18
A. prasina KU326673
L19
A. fasciolata LSUHC8837
A. fasciolata LSUHC9831
L21
Ahaetulla sp. CESS318
Ahaetulla sp. CESS259
L22
OUTGROUP
OUTGROUP
P1 P3 G M GD
Trimeresurus
P1 P3 M G
CESS170
CESS015
CESS256
CESS527
CESS190
L 6
L 7
CESS108
CESS226
CESS223
CESS086
CESS141
CESS053
CESS154
CESS515
CESS155
CESS525
CESS273
CESS054
L 5
II
IV
CESS166
CESS181
CESS178
L 3
L 4
CESS257
CESS074
CESS101
CESS100
CESS032
CESS056
CESS285
T. gramineus B261
L 1
CESS147
CESS369
CESS378
CESS033
L 2
CESS272
CESS040
III
A
V
T. trigonocephalus
T. strigatus CESS142
I
T. borneensis
T. puniceus
B
Other Trimeresurus
Outgroup

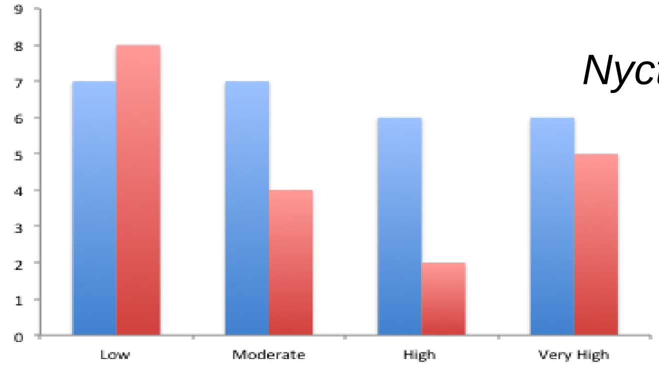
Wallace meets Linnaeus and Darwin



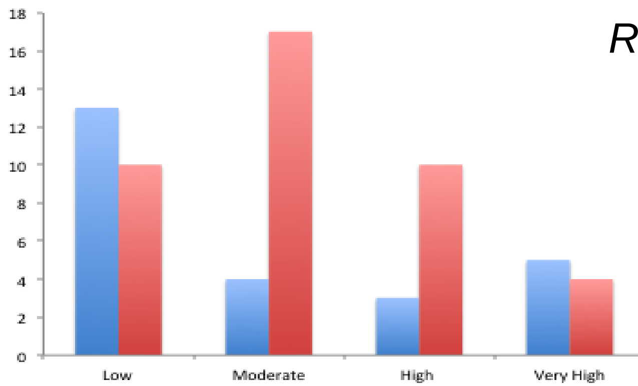
Identifying sister lineages with confidence



Micrixalus



Nyctibatrachus

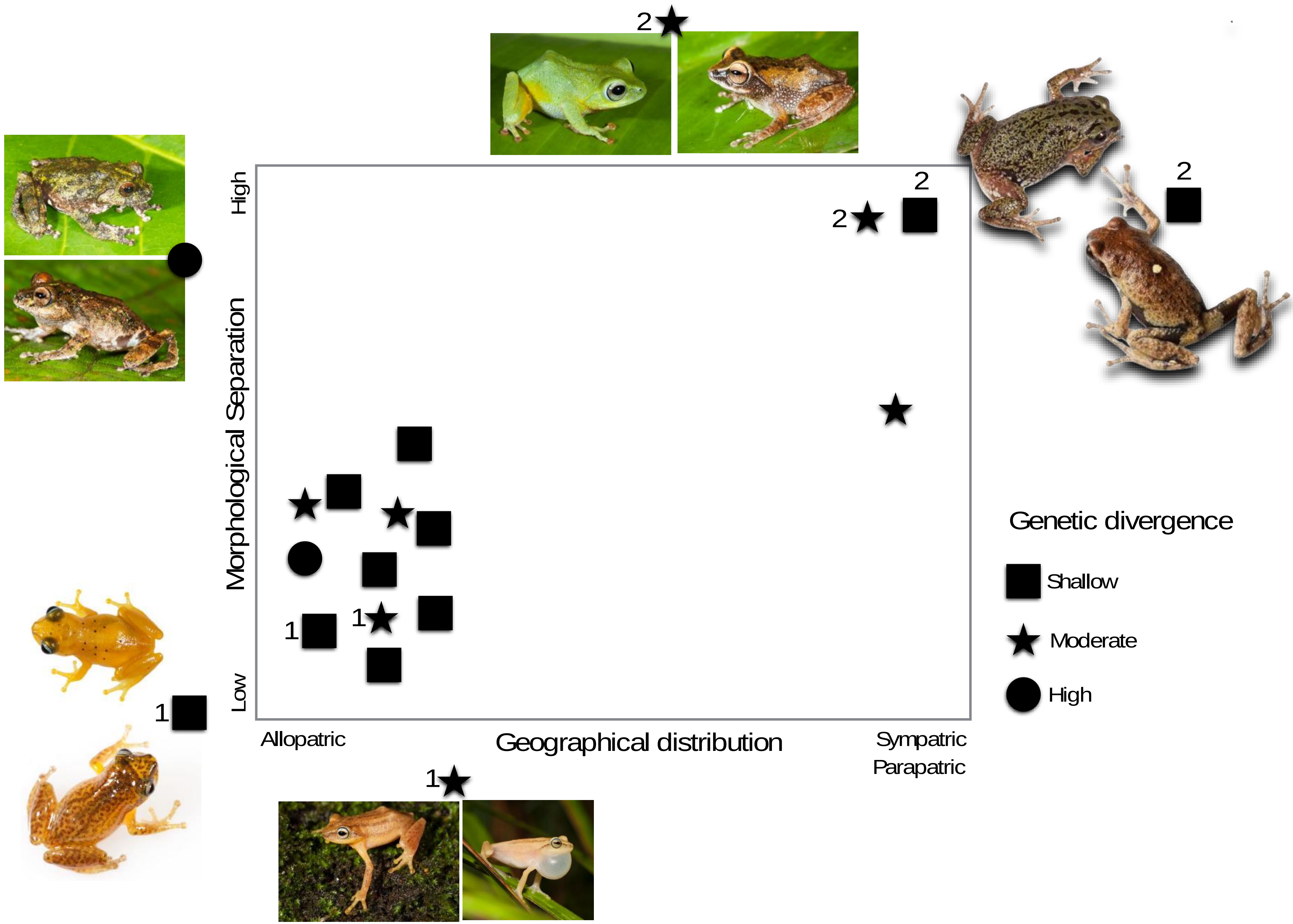


Raorchestes

Known lineages

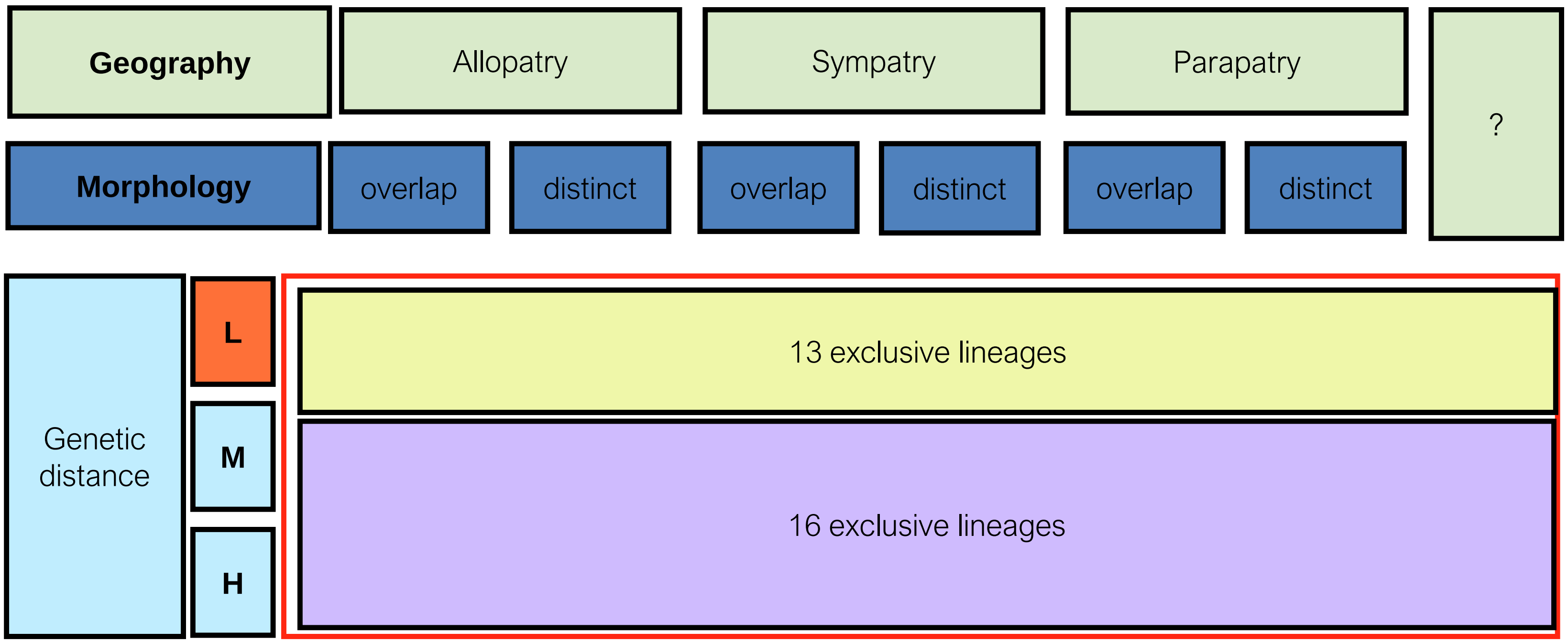
Putative new lineages

New lineages across levels of divergence in all taxa



High
Morphological Separation
Low
Allopatric
Geographical distribution
Sympatric
Parapatric
Genetic divergence
Shallow
Moderate
High
1
2

Lineages in multi-dimensional space



General lineage concept

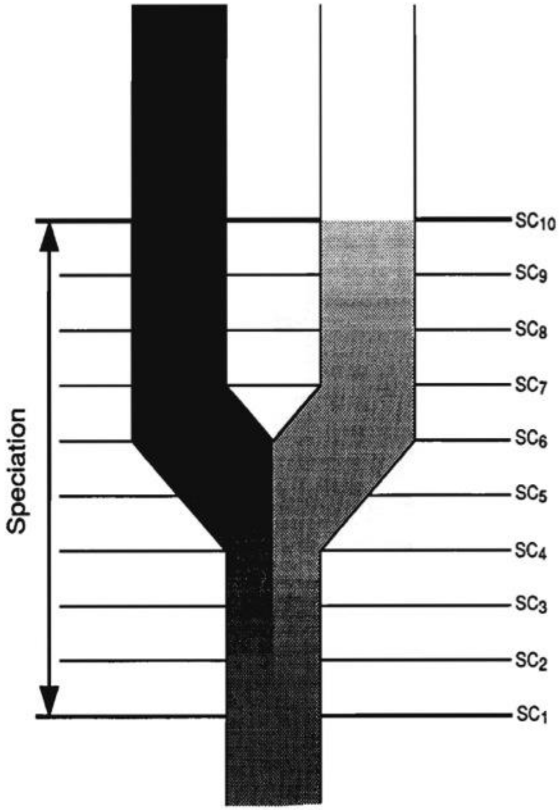
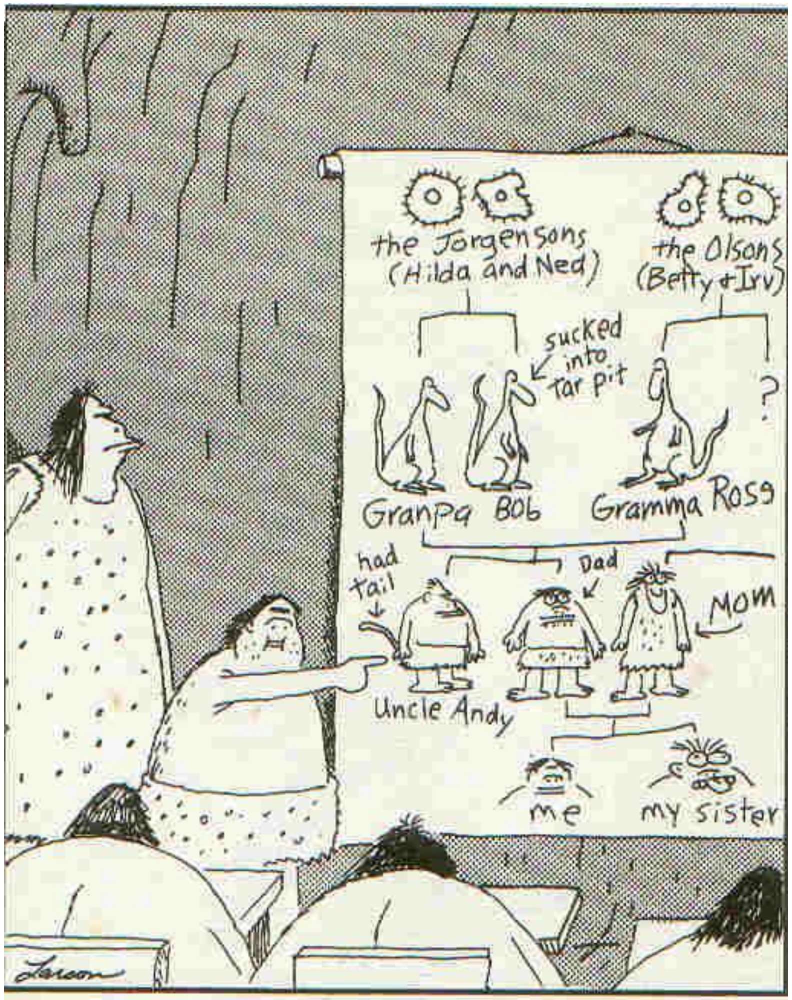
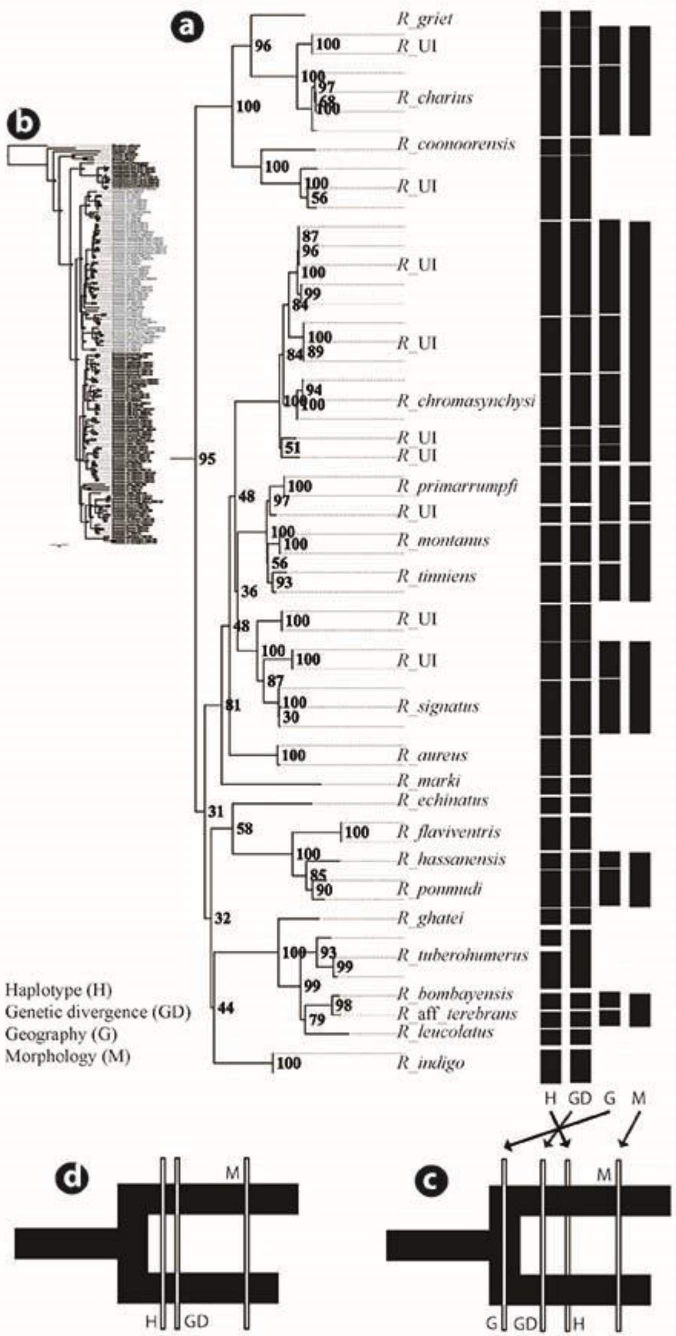


Figure 5.4. Speciation and species criteria. In this generalized diagram, speciation is equated with the entire set of events whose individual members serve as the basis for different species criteria; it is bounded by the first and last events in that set and is represented as a broad zone within which different species criteria, represented by horizontal lines (SC1–10), will result in different conclusions about the number of species.

Not so general lineage concept



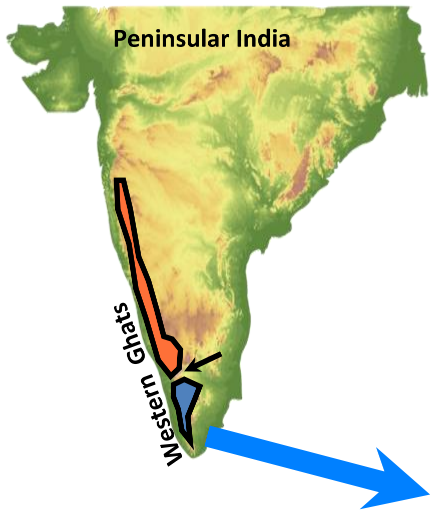
Dirk brings his family tree to class.

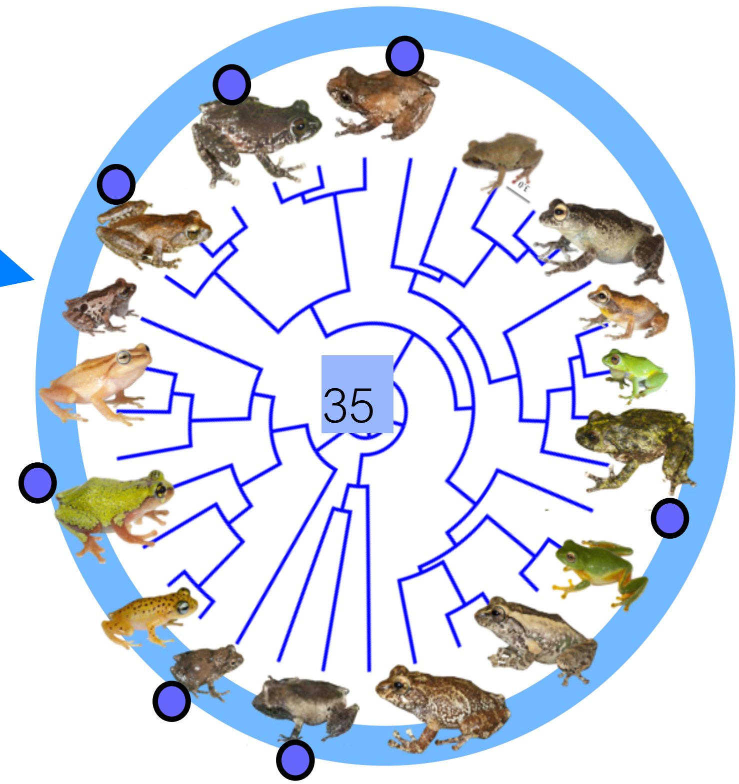


Morphological, genetic and geographical separation can occur at different rates and in different sequences, even within the same clade

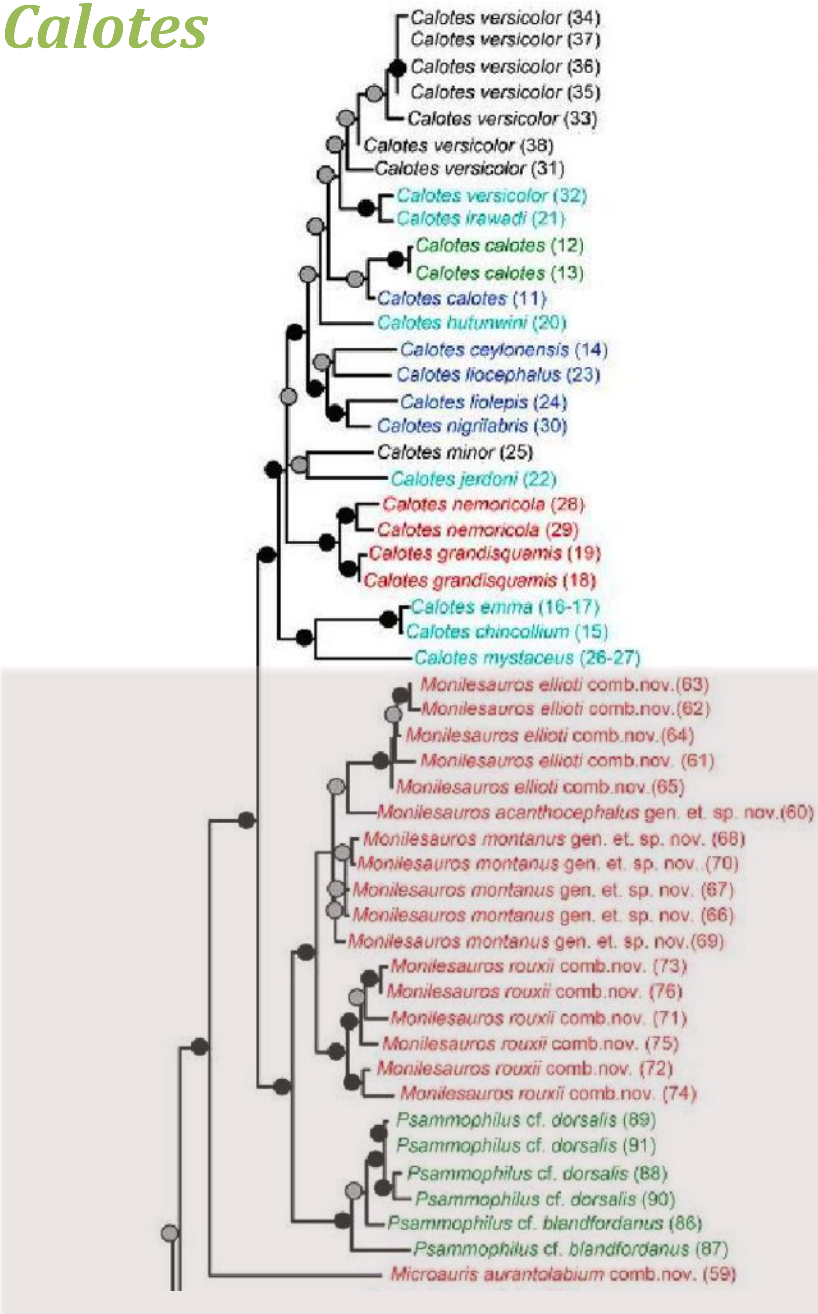
Vijayakumar et al (2016) *Proc B*
Shanker et al (2017) *J Genetics*

Starting out: an evolutionary perspective



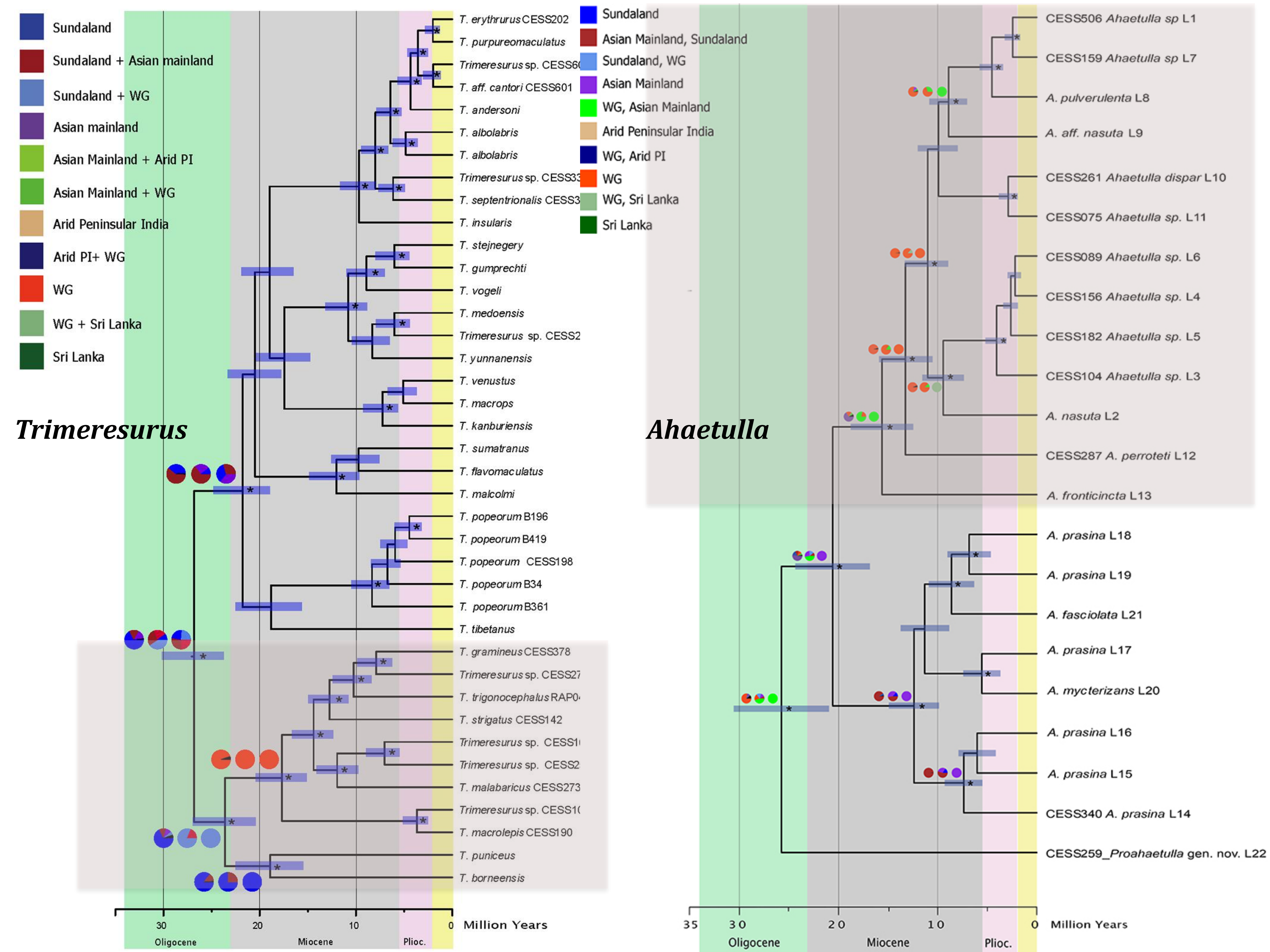


Calotes

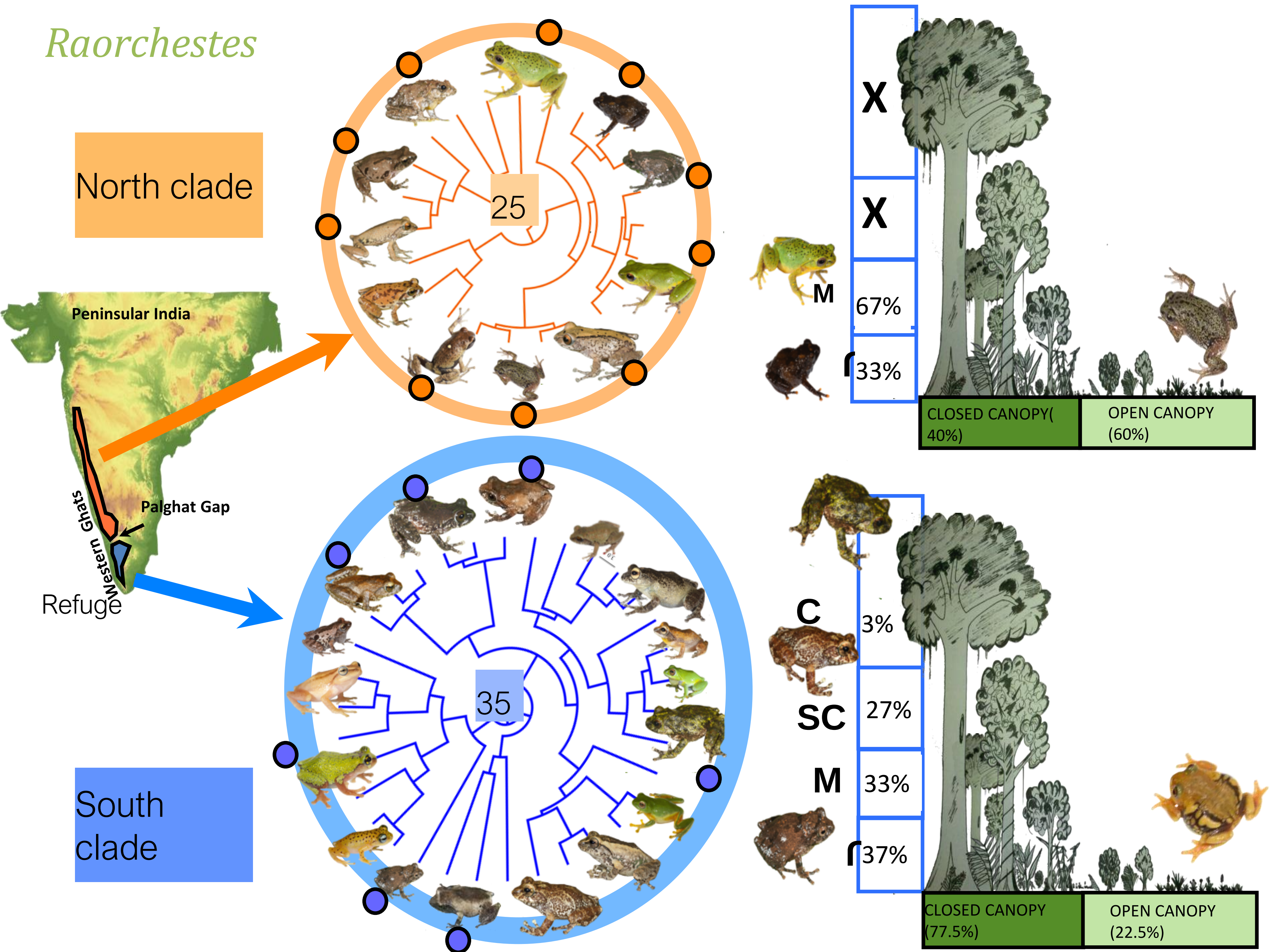


Monilesauros rouxii comb. nov.

Microauris aurantolabium comb. nov.



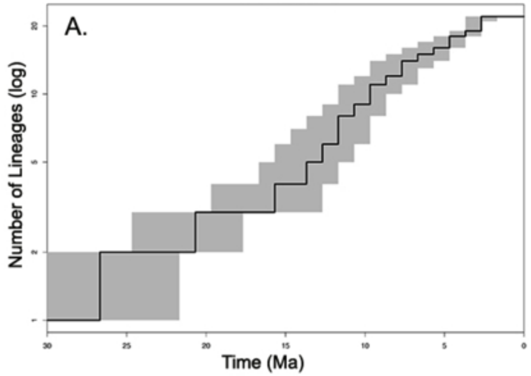
Trimeresurus
Sundaland
Sundaland + Asian mainland
Sundaland + WG
Asian mainland
Asian Mainland + Arid PI
Asian Mainland + WG
Arid Peninsular India
Arid PI+ WG
WG
WG + Sri Lanka
Sri Lanka
T. erythrurus CESS202
T. purpureomaculatus
Trimeresurus sp. CESS6
T. aff. cantori CESS601
T. andersoni
T. albolabris
T. albolabris
Trimeresurus sp. CESS3
T. septentrionalis CESS3
T. insularis
T. stejnegery
T. gumprechti
T. vogeli
T. medoensis
Trimeresurus sp. CESS2
T. yunnanensis
T. venustus
T. macrops
T. kanburiensis
T. sumatranus
T. flavomaculatus
T. malcolmi
T. popeorum B196
T. popeorum B419
T. popeorum CESS198
T. popeorum B34
T. popeorum B361
T. tibetanus
T. gramineus CESS378
Trimeresurus sp. CESS27
T. trigonocephalus RAP0
T. strigatus CESS142
Trimeresurus sp. CESS1
Trimeresurus sp. CESS2
T. malabaricus CESS273
Trimeresurus sp. CESS1
T. macrolepis CESS190
T. puniceus
T. borneensis
30
20
10
0
Million Years
Oligocene
Miocene
Plioc.
Ahaetulla
Sundaland
Asian Mainland, Sundaland
Sundaland, WG
Asian Mainland
WG, Asian Mainland
Arid Peninsular India
WG, Arid PI
WG
WG, Sri Lanka
Sri Lanka
CESS506 Ahaetulla sp L1
CESS159 Ahaetulla sp L7
A. pulverulenta L8
A. aff. nasuta L9
CESS261 Ahaetulla dispar L10
CESS075 Ahaetulla sp. L11
CESS089 Ahaetulla sp. L6
CESS156 Ahaetulla sp. L4
CESS182 Ahaetulla sp. L5
CESS104 Ahaetulla sp. L3
A. nasuta L2
CESS287 A. perroteti L12
A. fronticincta L13
A. prasina L18
A. prasina L19
A. fasciolata L21
A. prasina L17
A. mycterizans L20
A. prasina L16
A. prasina L15
CESS340 A. prasina L14
CESS259_Proahaetulla gen. nov. L22
35
30
20
10
0
Million Years
Oligocene
Miocene
Plioc.

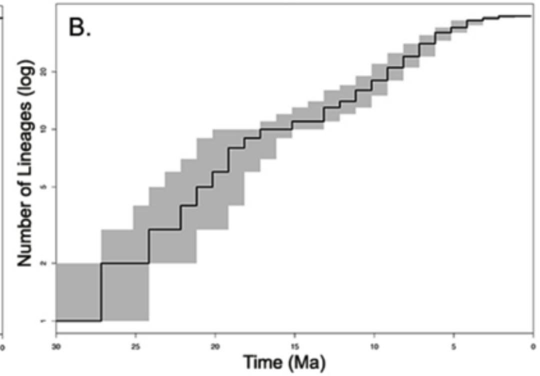


Raorchestes
North clade
25
Peninsular India
Palghat Gap
Western Ghats
Refuge
35
South clade
X
X
M
67%
33%
CLOSED CANOPY(40%)
OPEN CANOPY (60%)
C
3%
SC
27%
M
33%
37%
CLOSED CANOPY (77.5%)
OPEN CANOPY (22.5%)

Trimeresurus

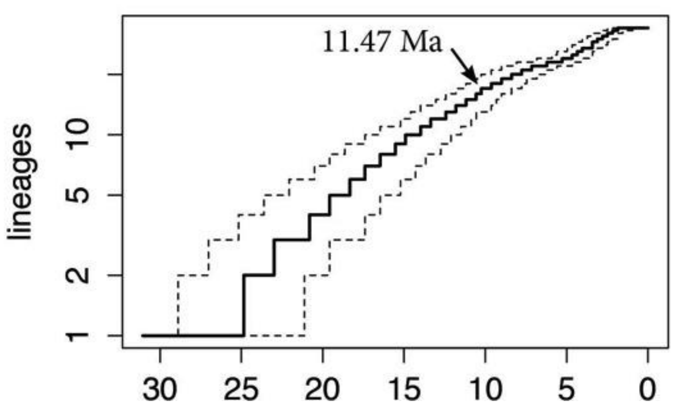
Ahaetulla



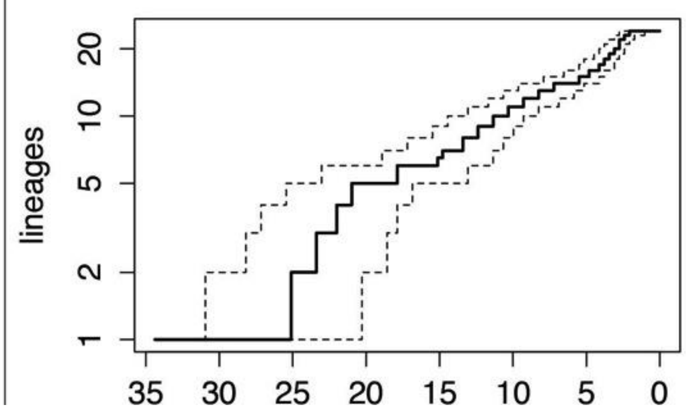


Raorchestes

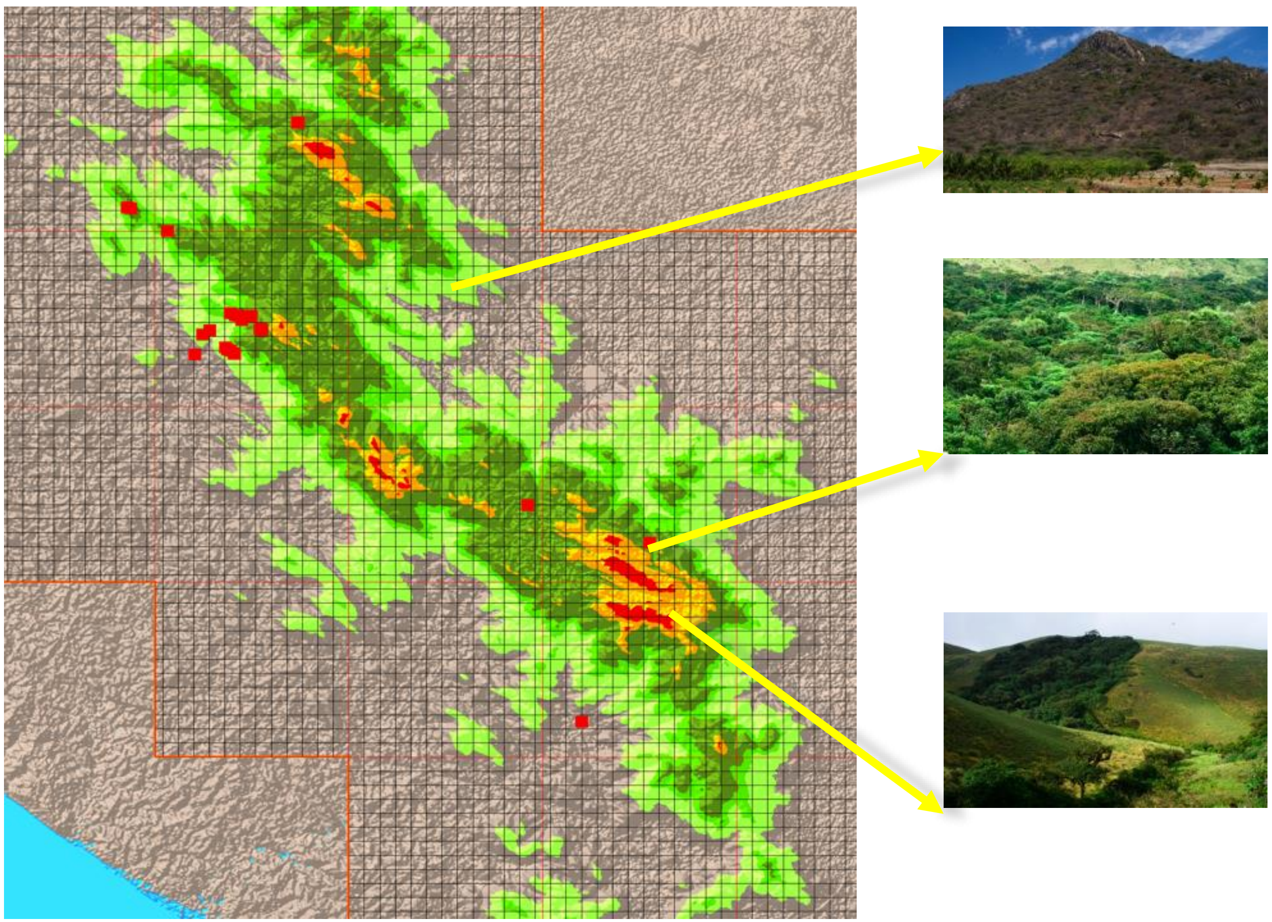
South clade



North clade



Getting there and staying alive: a macroecological view



Gradients in Species Richness

PATTERNS

Latitudinal
Altitudinal
Bathymetric

MECHANISMS

Temperature
Precipitation
Area
Productivity
Historical factors
Rapoport’s rule
Mid Domain Effect

Environmental factors

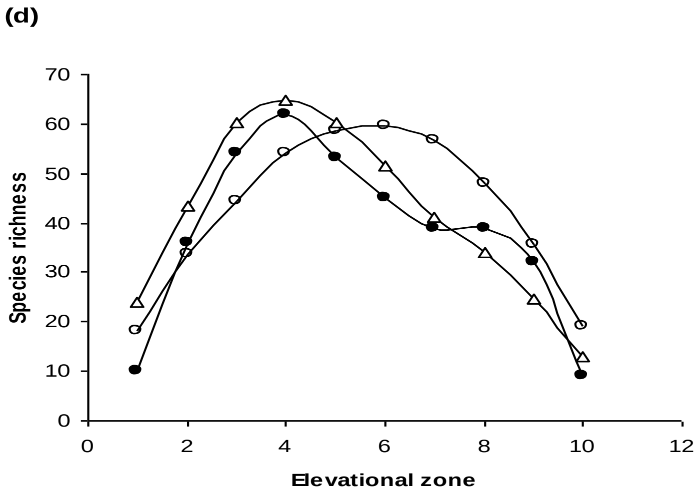
- Solar energy
  - Solar radiation and altitude/latitude
  - Temperature (Range, mean, maximum, minimum)

- Wind and Rainfall
  - Precipitation
  - Water stress
  - AET – Actual evapotranspiration
  - PET – Potential evepotranspiration
  - Wind patterns (global and local scales)

- Soil
- Productivity (Biomass, Abundance)

The mid domain effect

- Geometric constraints
- Range size and position random
- Range limits constrained by boundaries
- Alternate models with empirical range size distributions or empirical range mid-points



Combining range and environment

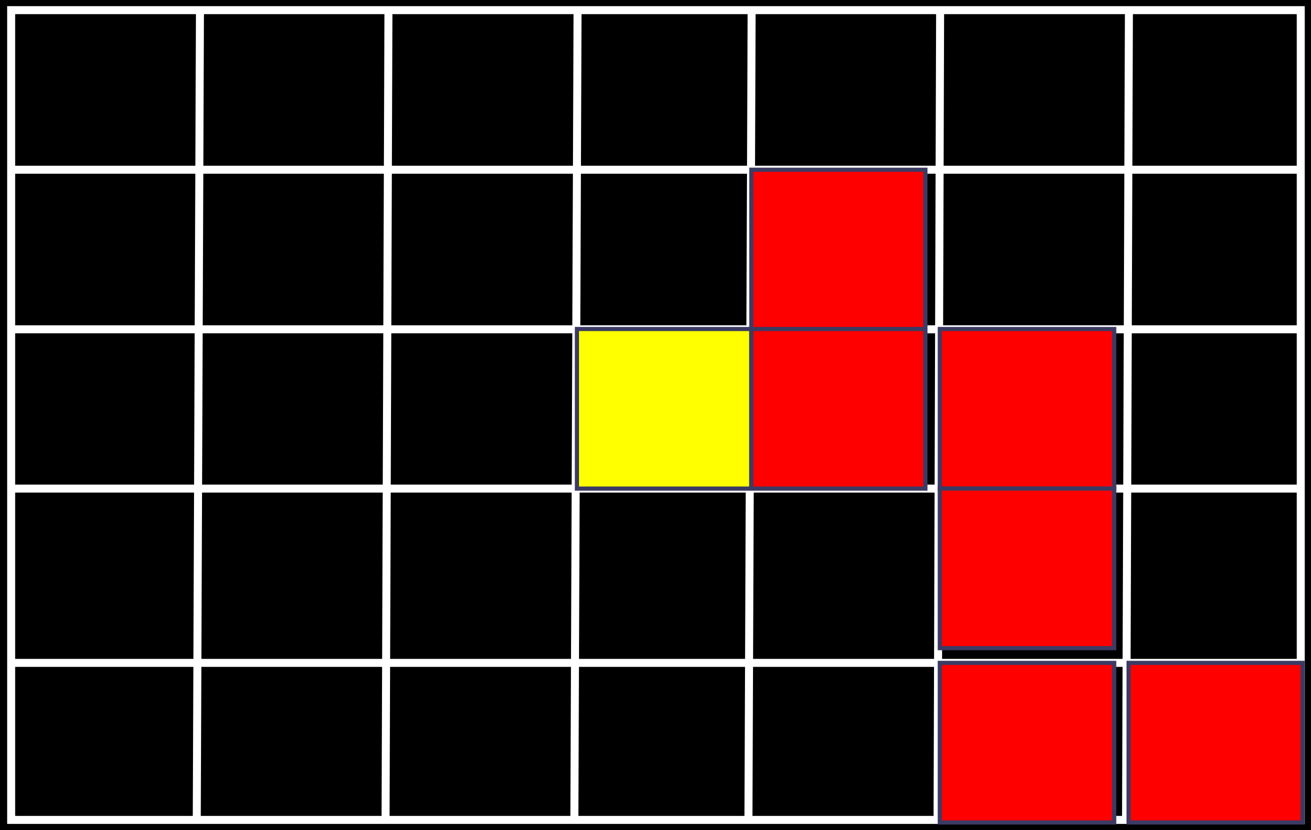
- ➢ Environmental patterns
- ➢ Range based explanations
    - •Mid domain effect

- ➢ Range cohesion and range scatter models

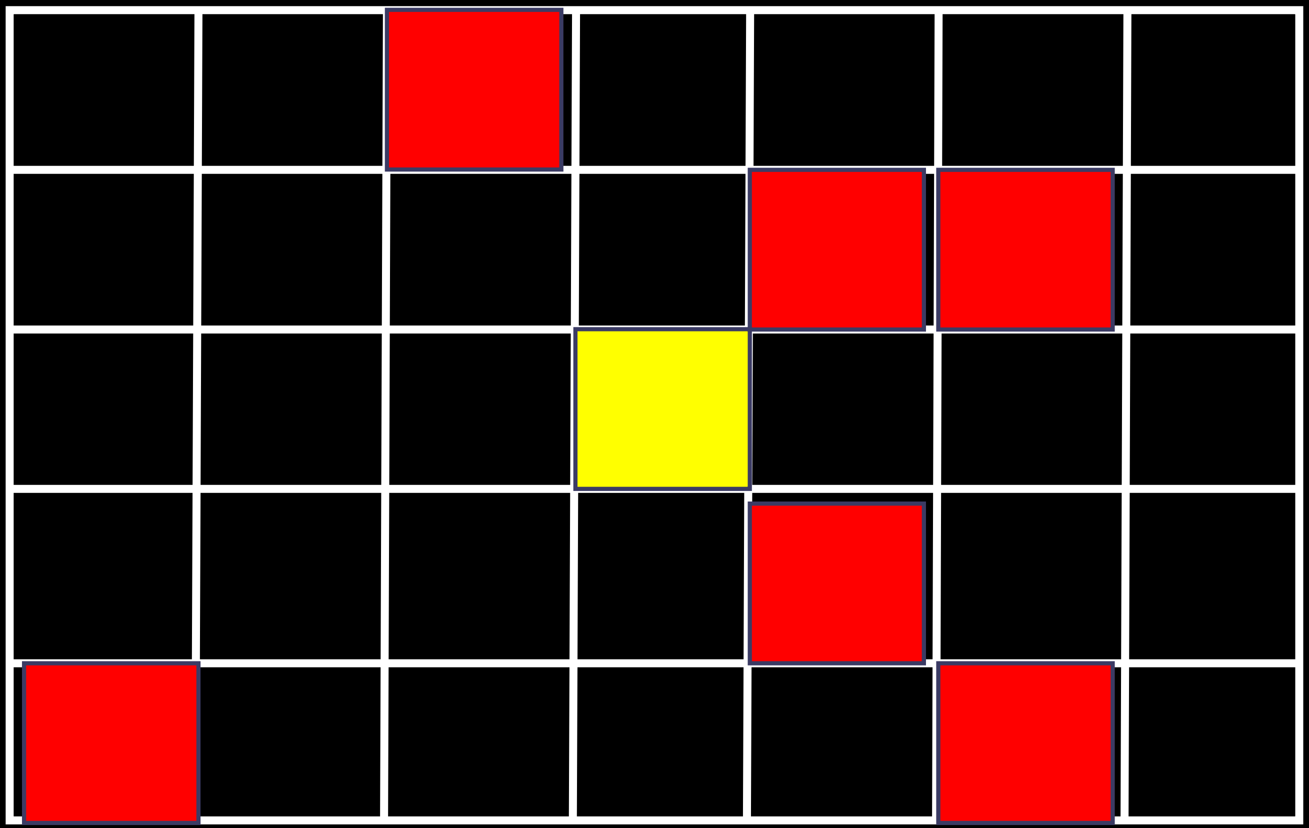
- ➢ Modeling the distribution of organisms based on the assumption that ranges are contiguous (as one would expect from dispersal) and that they are not

- ➢ Using both frameworks with occurrence probabilities based on environmental parameters

Range cohesion models

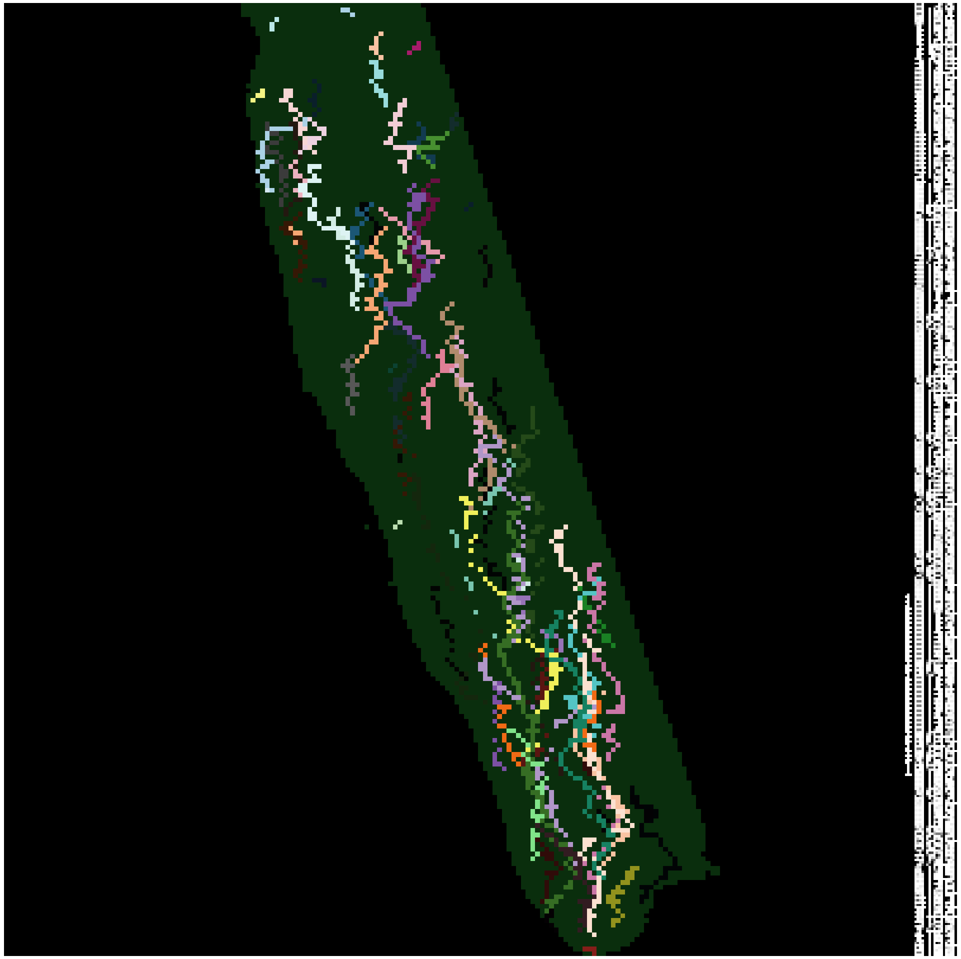


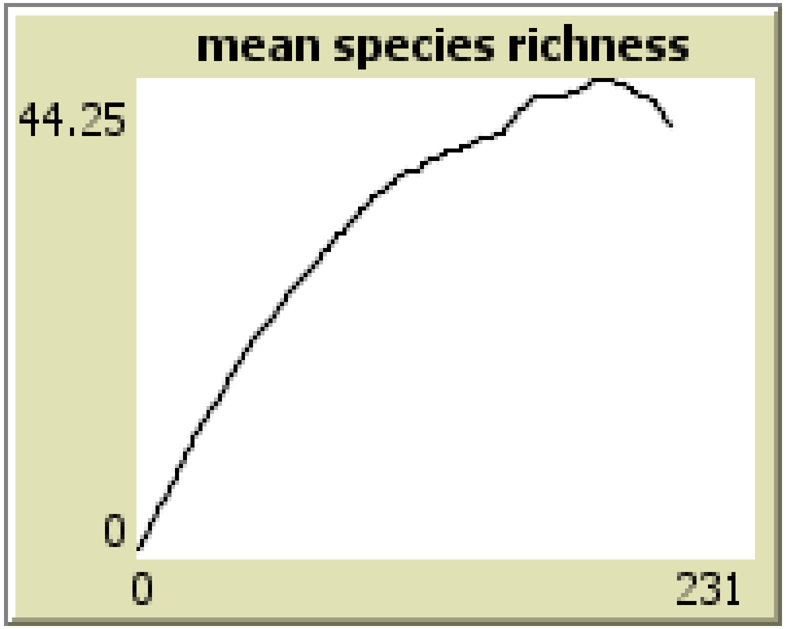
Range scatter models



Implication: everything is everywhere (Bejerinck's law)

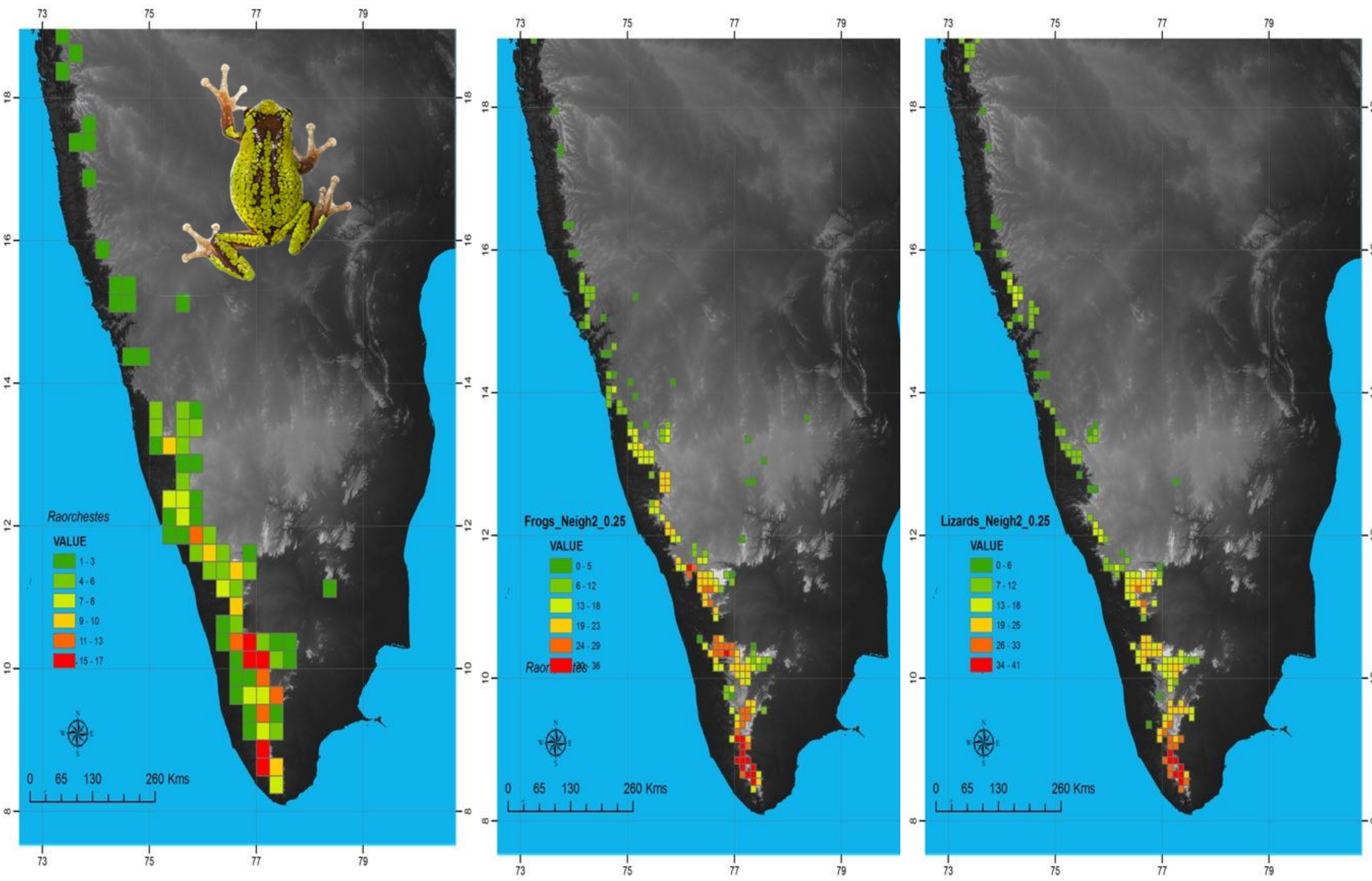
A cohesion – temperature model



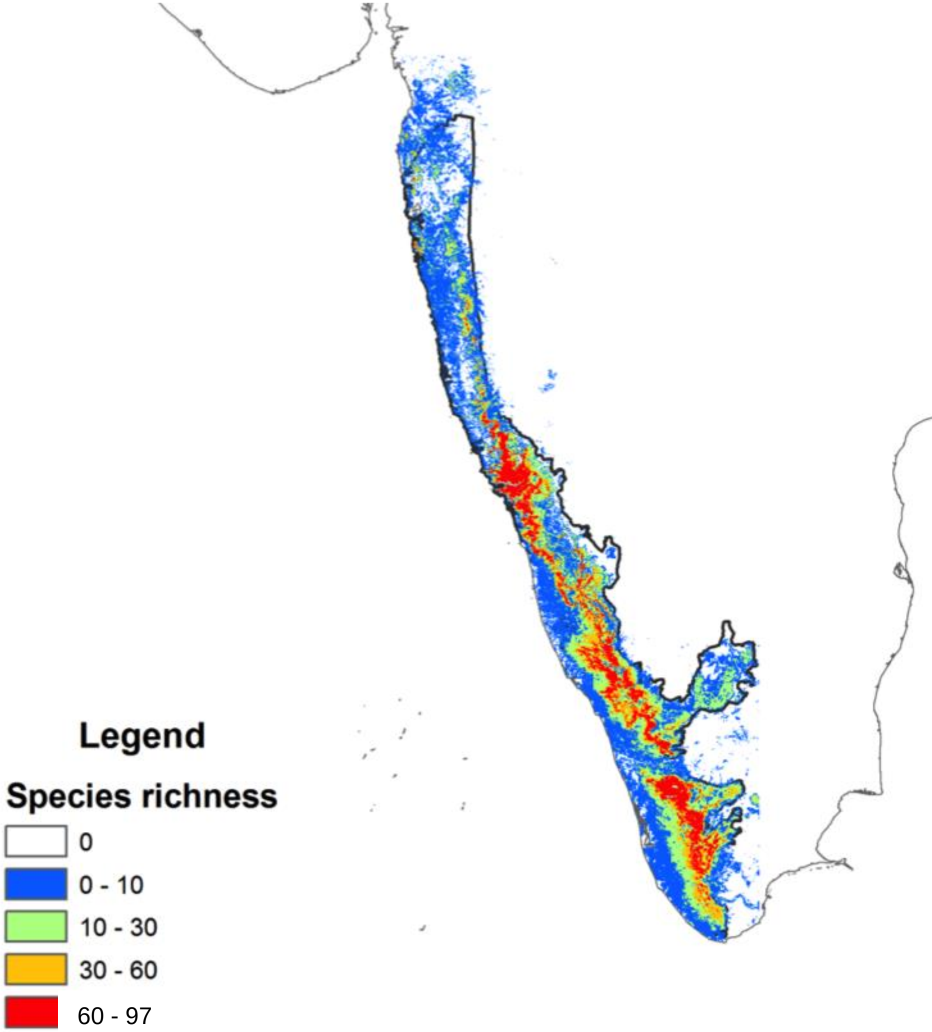


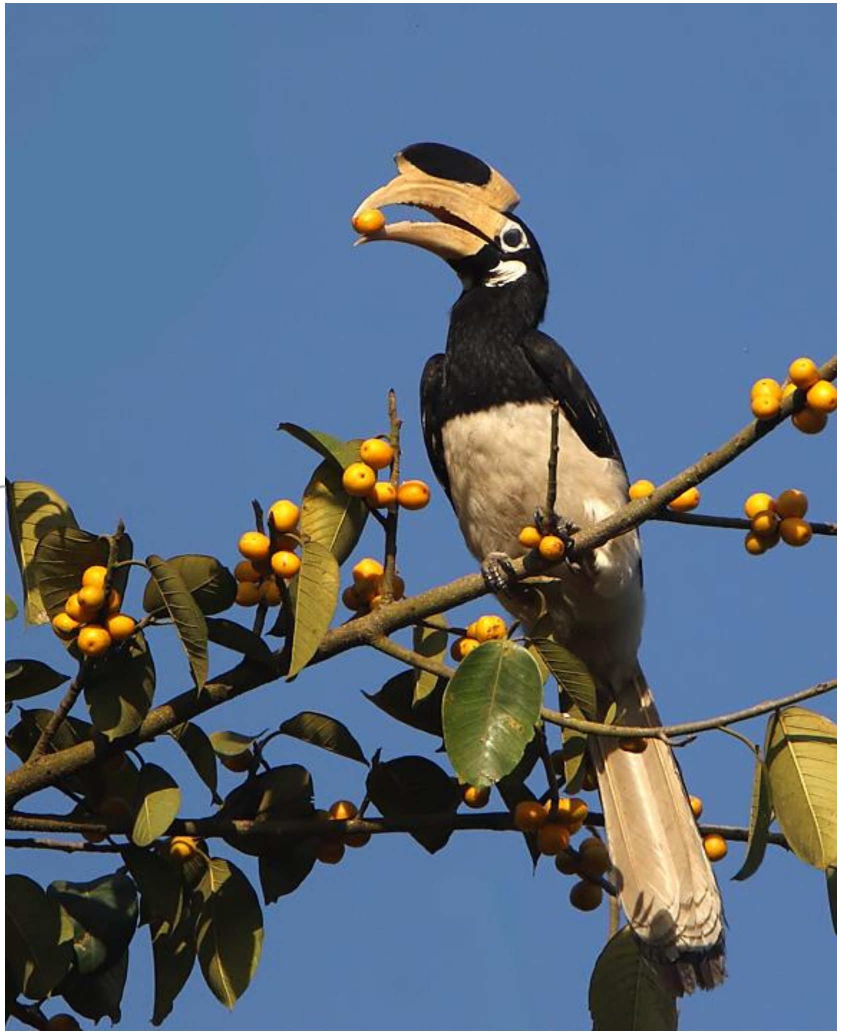
Model that combines range overlap and temperature provides best visual fit to empirical data for many taxa

Frog and Lizard richness maps for the WG

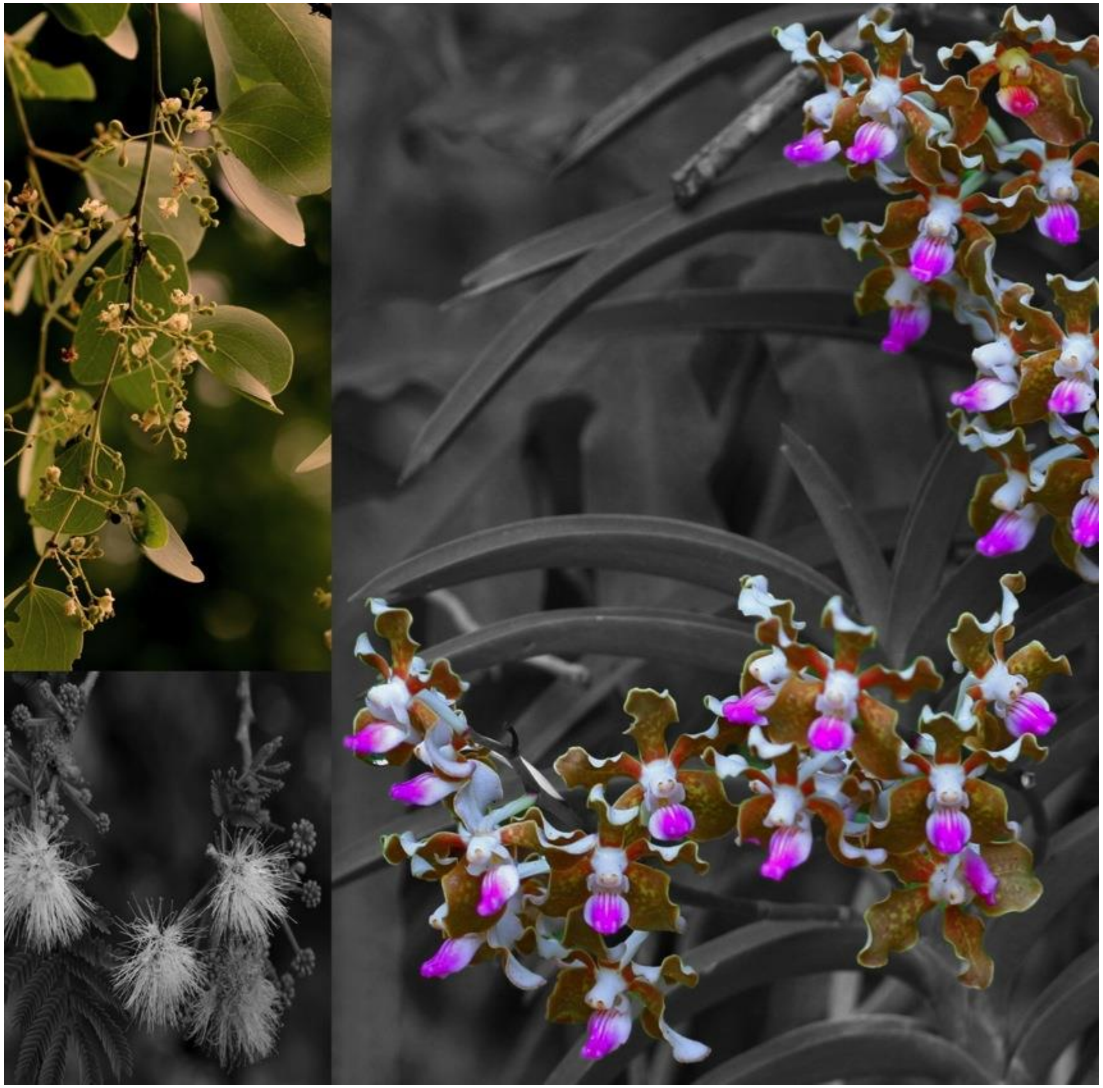


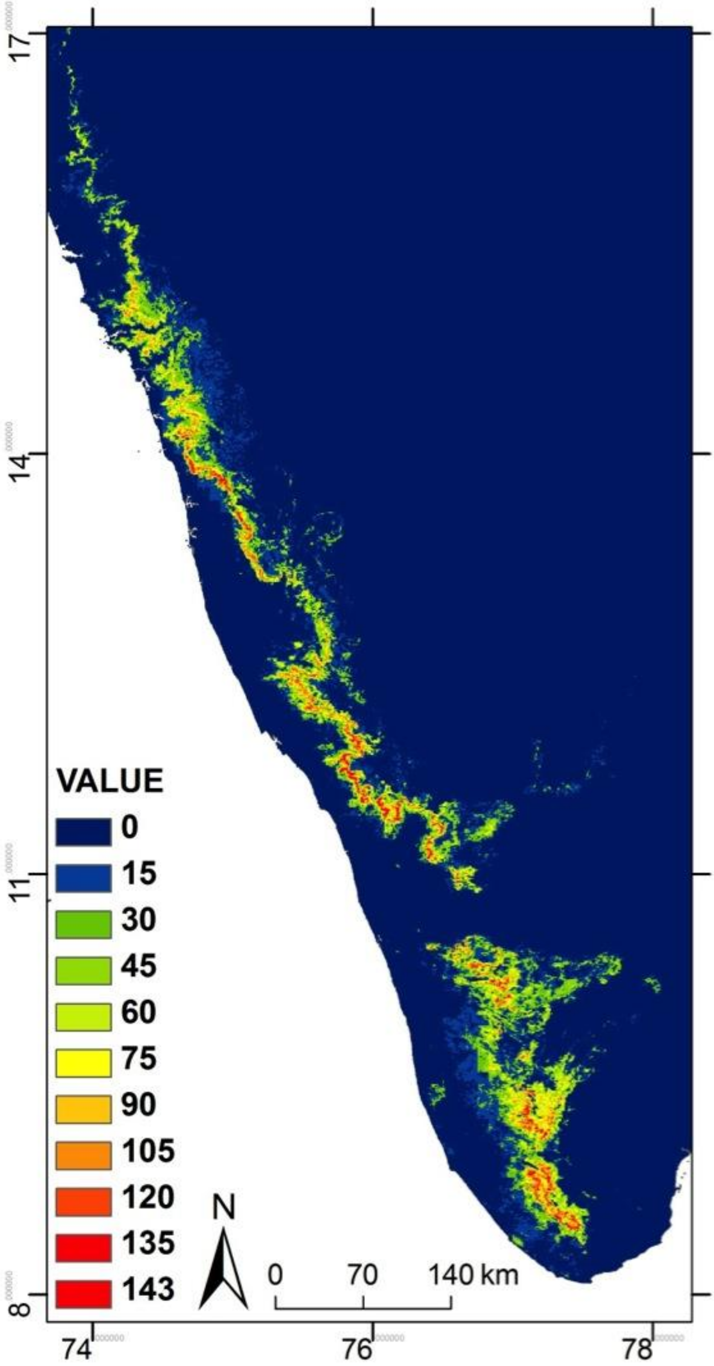
Bird richness map for the WG



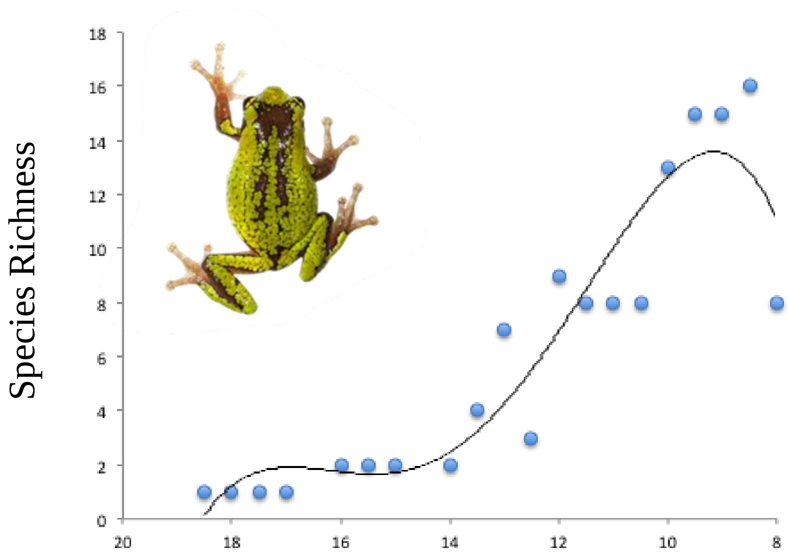


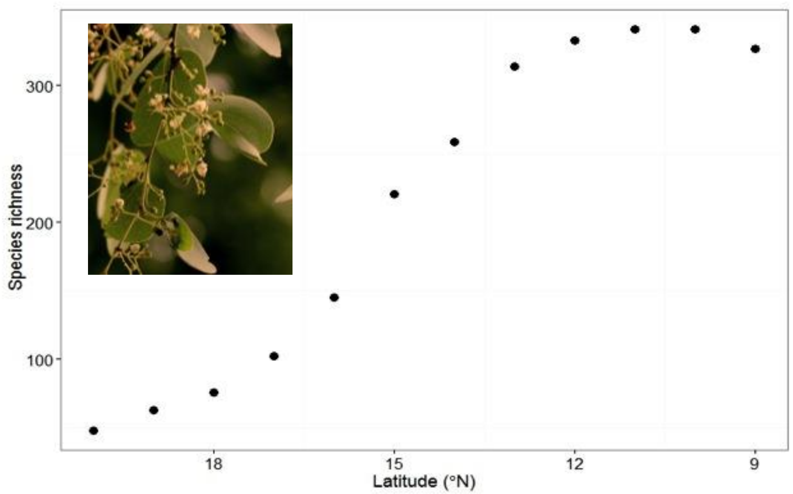
Tree richness map for the WG

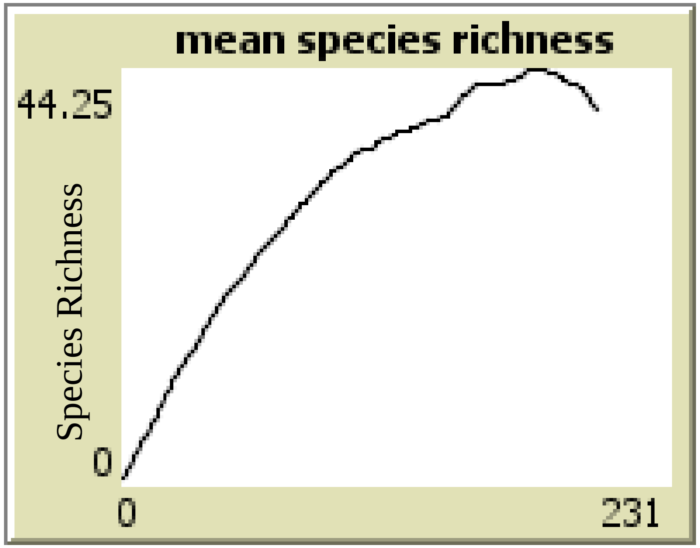




Range Cohesion in an empirical grid of WG







Feasible ranges and Linear Temperature Gradient

Summary

- Using a spatially explicit biogeographic approach for discovery and delimitation of lineages forms the basis of further analysis

- A replicable step-wise multi-criteria approach for delimitation

- Combining range, environment and evolution is critical for understanding diversity
    - Ecological dispersal plays a greater role in some groups (birds, some plants)
    - Diversification plays a greater role in some groups (frogs, some plants)
    - Significant role of both in some groups (lizards, snakes, some plants)

- In-situ diversification of many clades in Peninsular India, with Western Ghats serving as a hotspot; different models of diversification

Researchers and collaborators

PROJECT researchers:

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Achyuthan Srikanthan (Snakes)
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Deepak Veerappan(Lizards)
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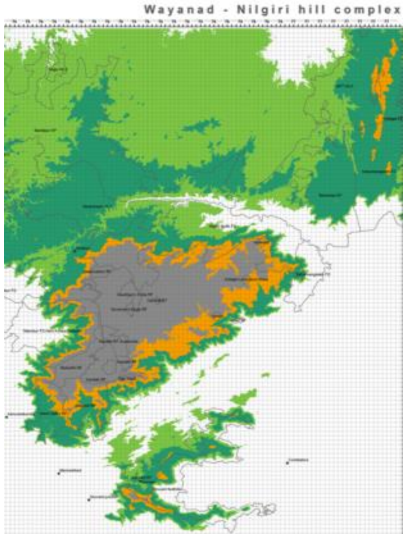
PROJECT SUPPORT

- CEPF
- INDIAN INSTITUTE OF SCIENCE (IISc)
- ATREE
- Ministry of Environment and Forests
- Kerala Forest Department
- Karnataka Forest Department
- Tamil Nadu Forest Department
- Maharashtra Forest Department
- FIELD AND EXPEDITION Members



CRITICAL ECOSYSTEM PARTNERSHIP FUND

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Thank you