

Müllerian mimicry shapes species assemblages and climatic niche evolution in Ithomiine butterflies

Maël Doré

Marianne Elias, Colin Fontaine,
Keith Willmott

Virtual Evolution – 2021



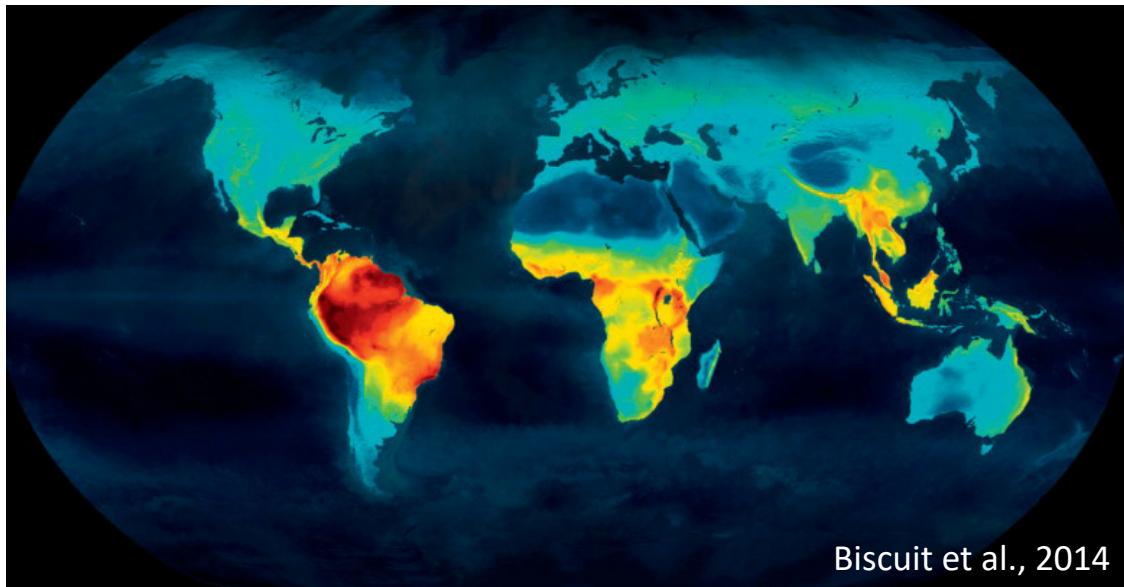
Credits: N. Chazot



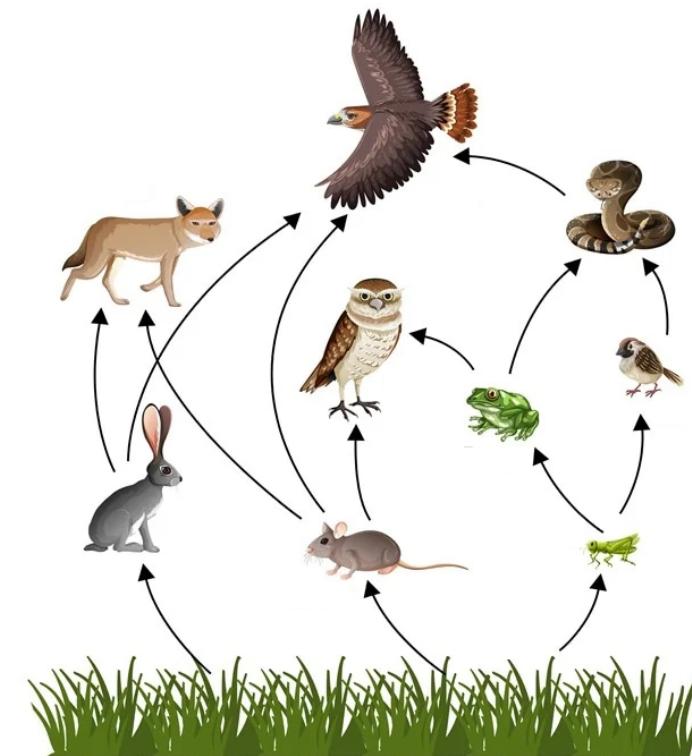
Context

Biodiversity

Biological units



Interactions



Credit: Shutterstock.com

Context

Biodiversity

Interactions

Negative



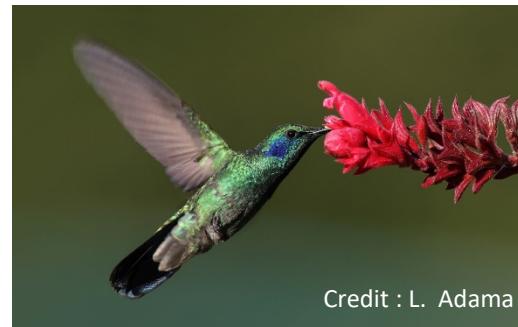
Inter-guild



Intra-guild



Positive



Credit : L. Adama

Adapted from Mallet, 2014

Context

Biodiversity

Interactions

	Inter-guild	Intra-guild
Negative	<p>Web of Science </p> <p>Results: 6,170 (from Web of Science Core Collection)</p> <p>You searched for: TOPIC: (community structure predation) ...More</p>	<p>Web of Science </p> <p>Results: 9,246 (from Web of Science Core Collection)</p> <p>You searched for: TOPIC: (community structure competition) ...More</p>
Positive	<p>Web of Science </p> <p>Results: 914 (from Web of Science Core Collection)</p> <p>You searched for: TOPIC: (community structure pollination) ...More</p>	<p>Web of Science </p> <p>Results: 56 (from Web of Science Core Collection)</p> <p>You searched for: TOPIC: (community structure mimicry) ...More</p>

Context

Biodiversity

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Context

Mutualistic interactions:

- Plant facilitation
- Cooperative hunting
- Anti-predatory dilution effect
- Müllerian mimicry



Credits: Amanda R. Liczner



©Thomas Kline ; salmonography.com



Credits: safari-consultants.com



Credits: Jason L. Brown

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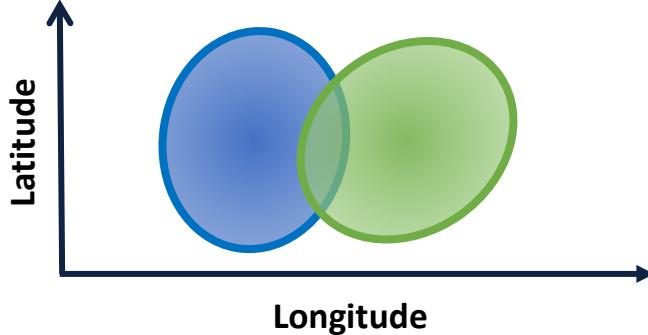
Exploitative competition:

- for local resources
- for habitats
- for space



Context

Spatial distribution



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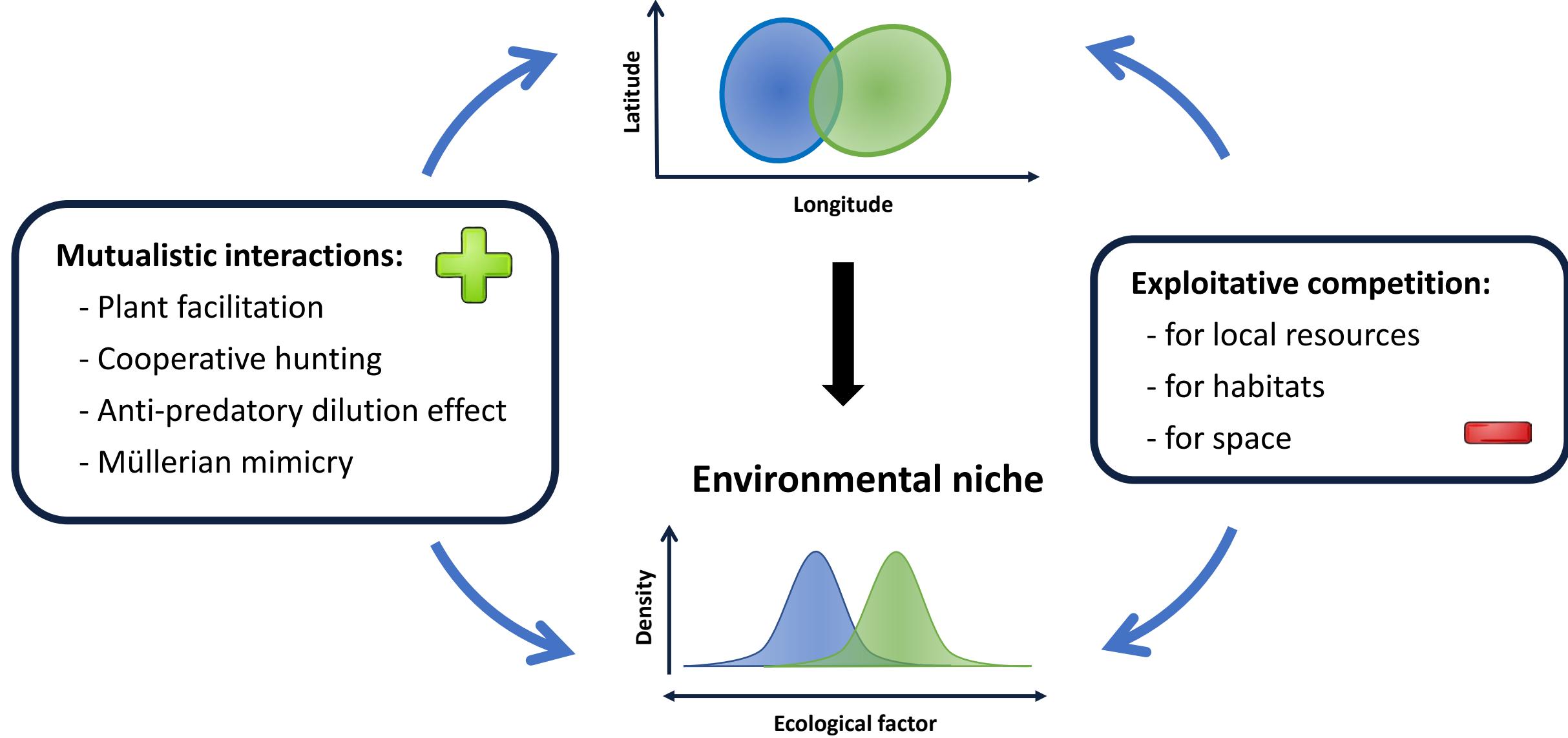


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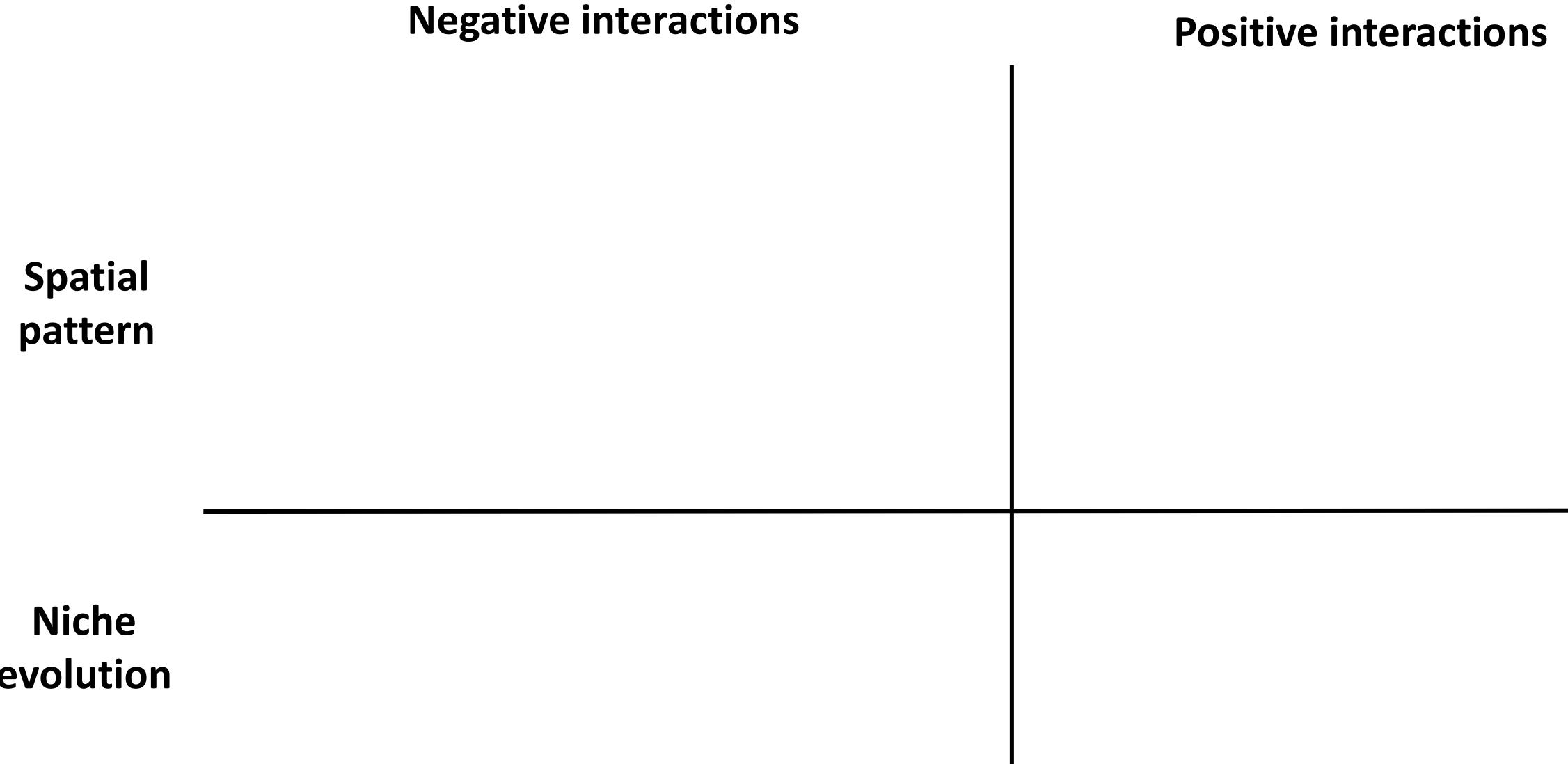
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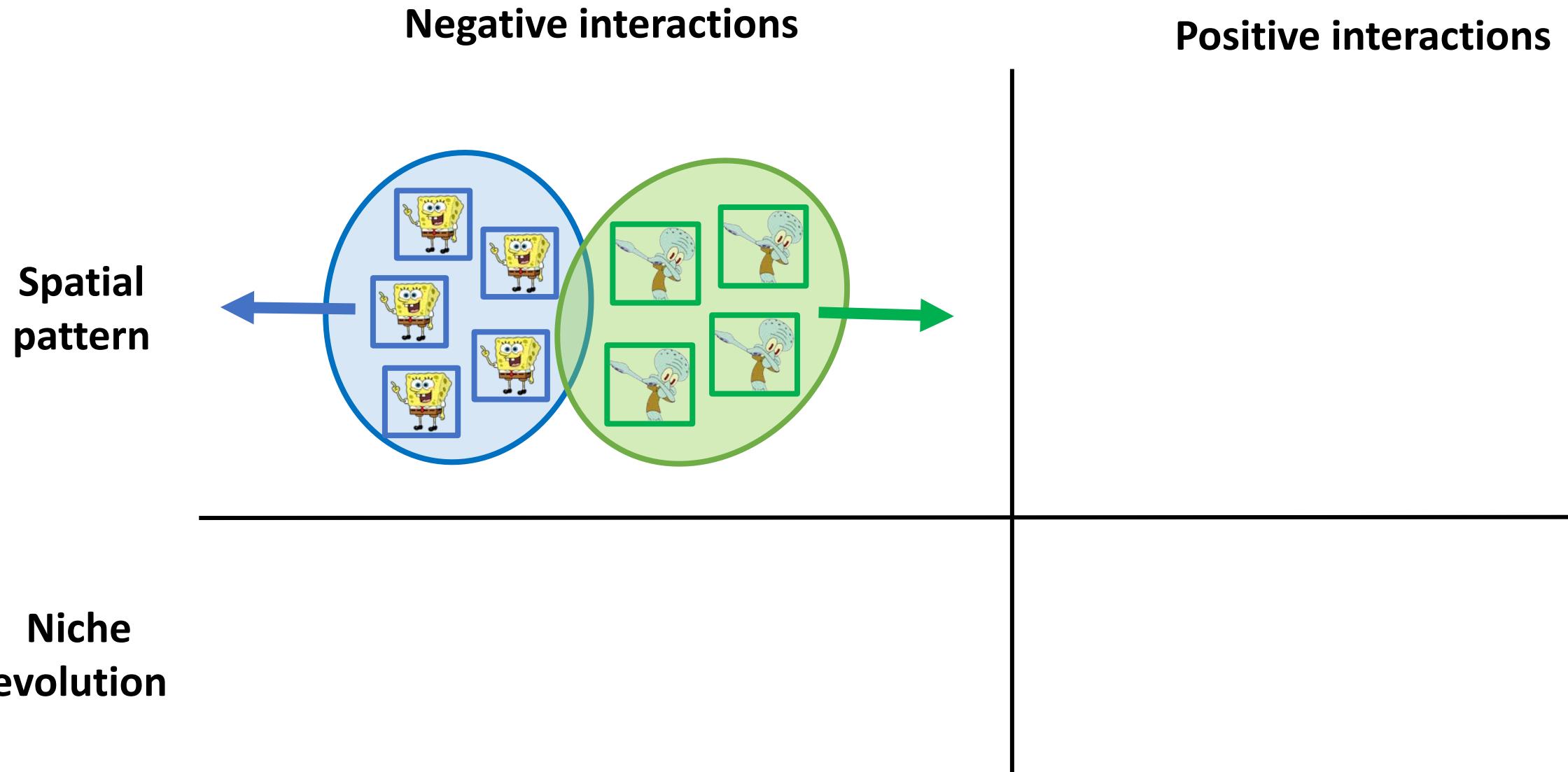
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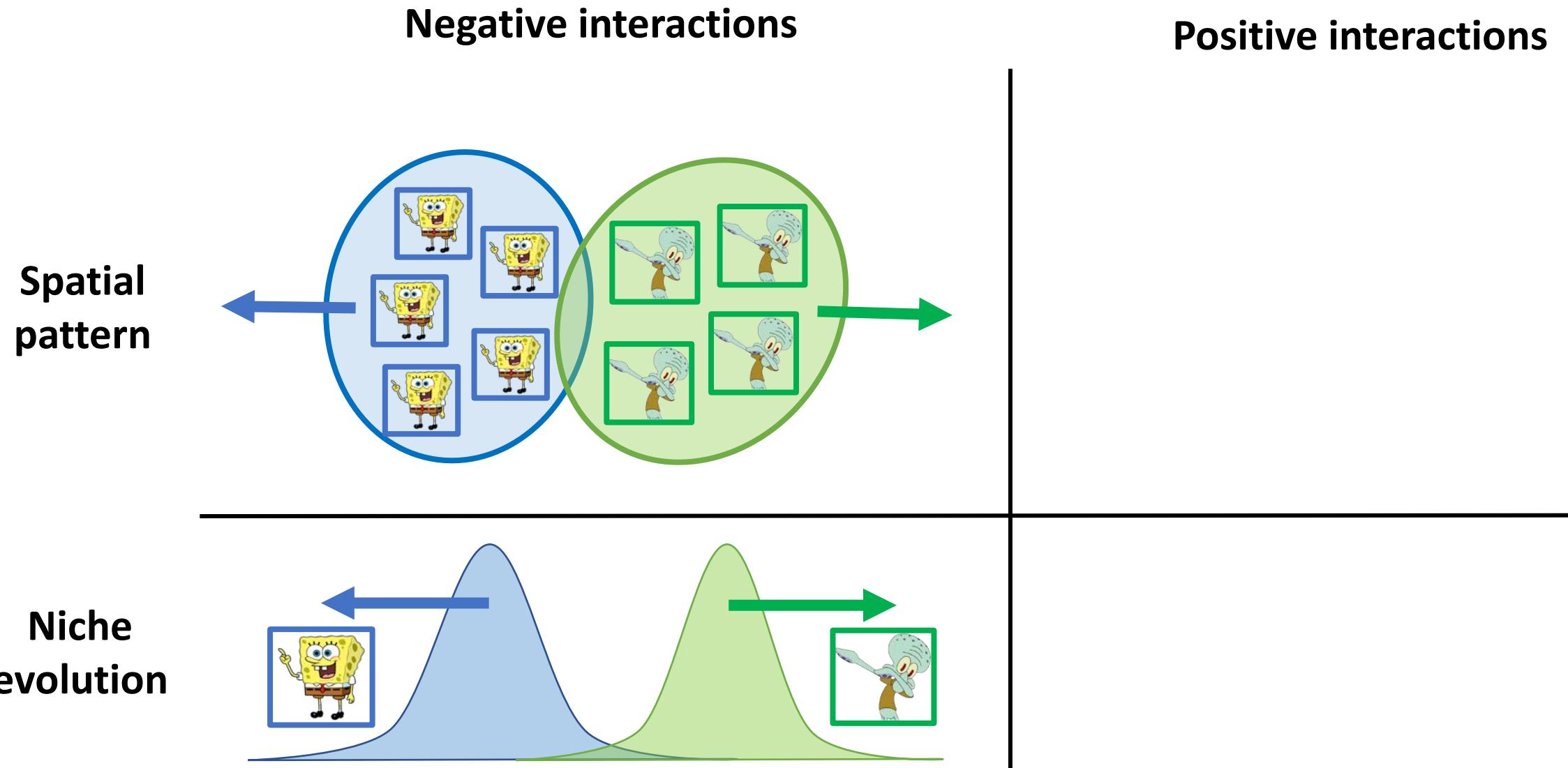
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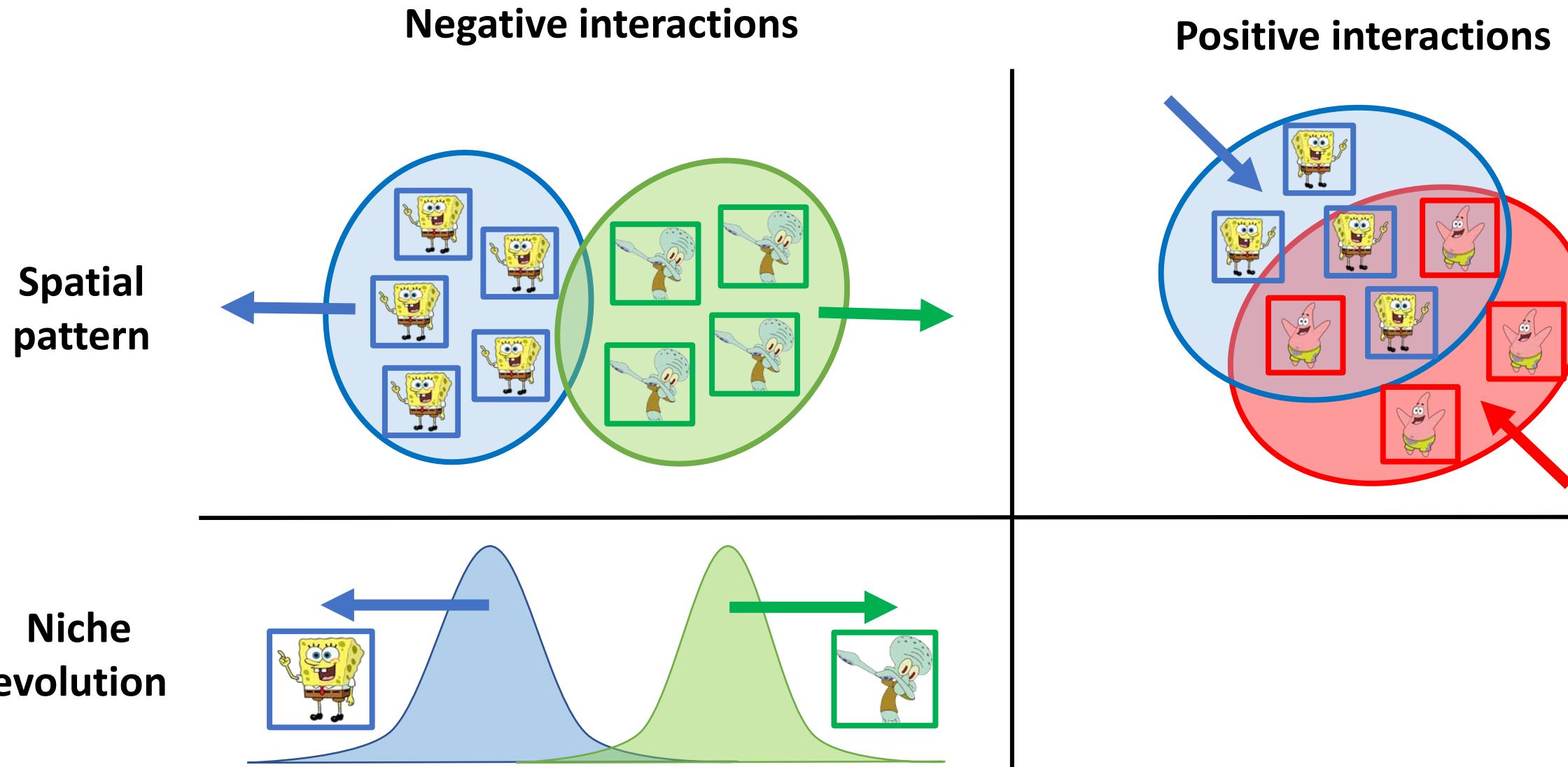
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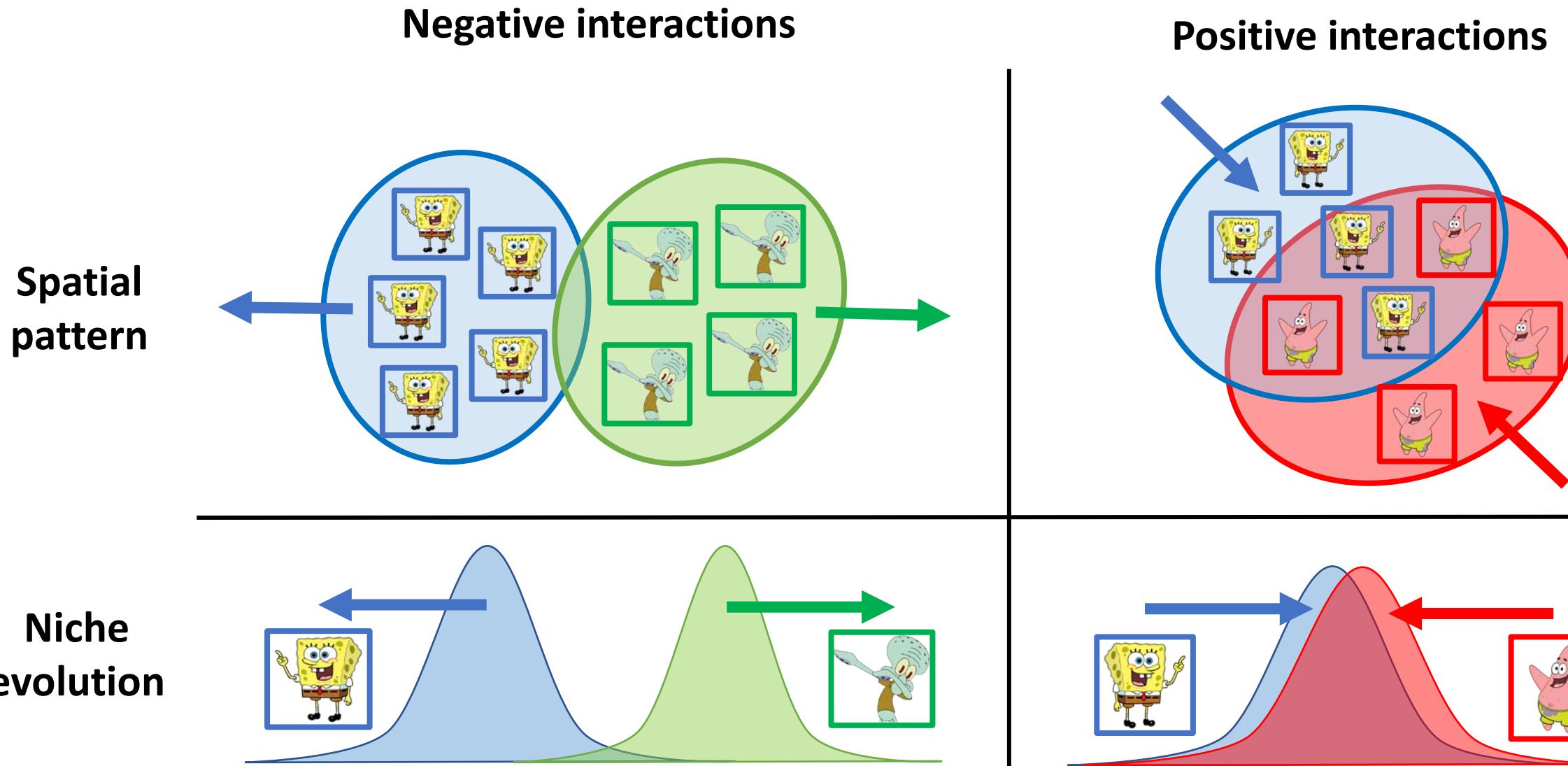
Context



Context



Context



Questions & Hypotheses

Can **intraguild positive interactions** outweigh the effects
of competition at the **macroecological scale**?

**Spatial
pattern**

Promote the large-scale **co-occurrence** of mutualistic species

**Niche
evolution**

Drive the **convergence** of the niche of mutualistic species

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Niche evolution

Drive the **convergence** of the niche of mutualistic species

Study system: Müllerian mimicry

Aposematism: warning signals

Shared signals = mutualistic interactions

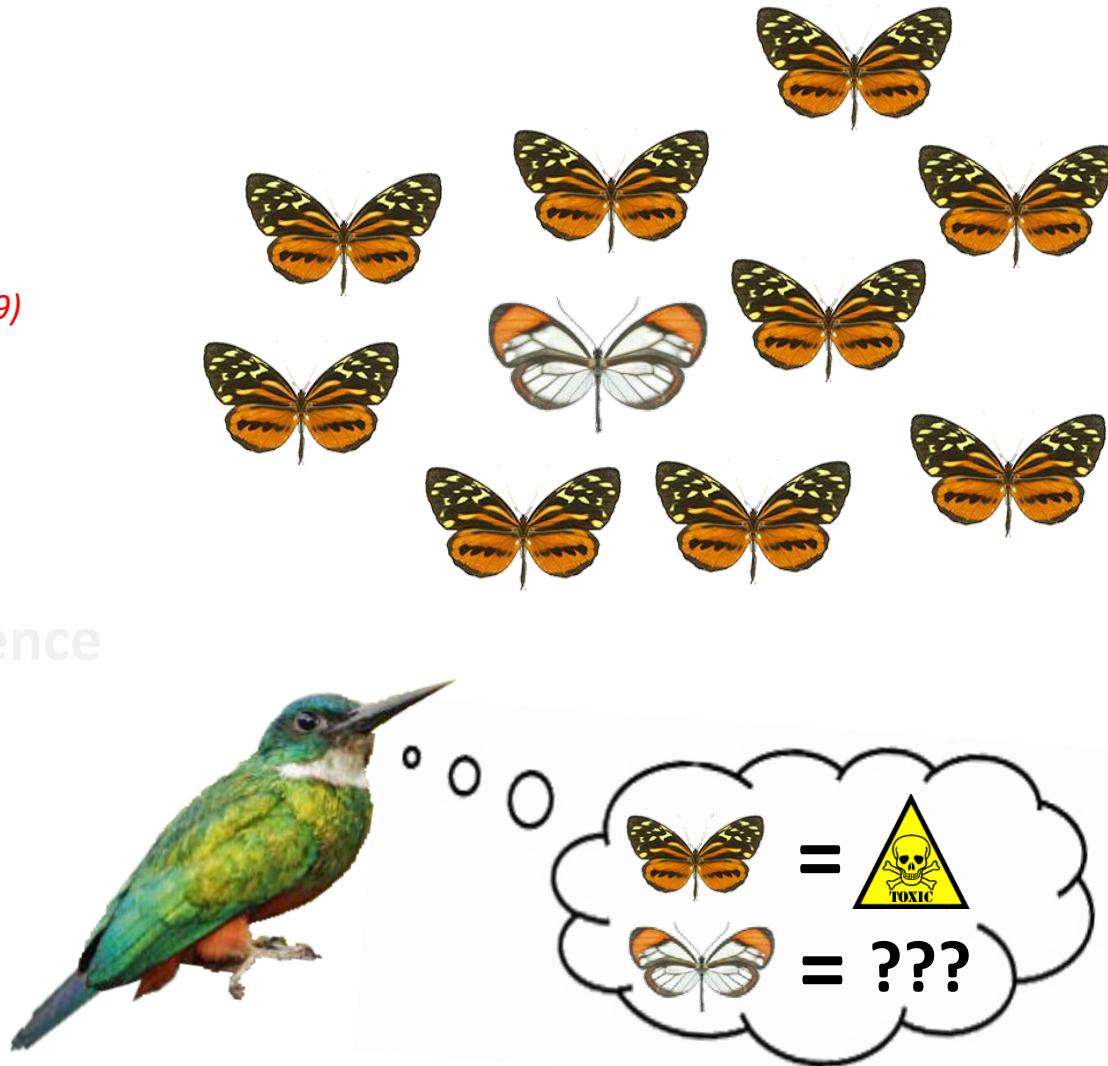
Positive frequency-dependent selection *(Müller, 1879)*

Consequences:

- Convergence of local patterns *(Sherratt, 2008)*
- Co-mimetic species benefit from co-occurrence

Macroecological scale?

- Community composition
- Species niche evolution



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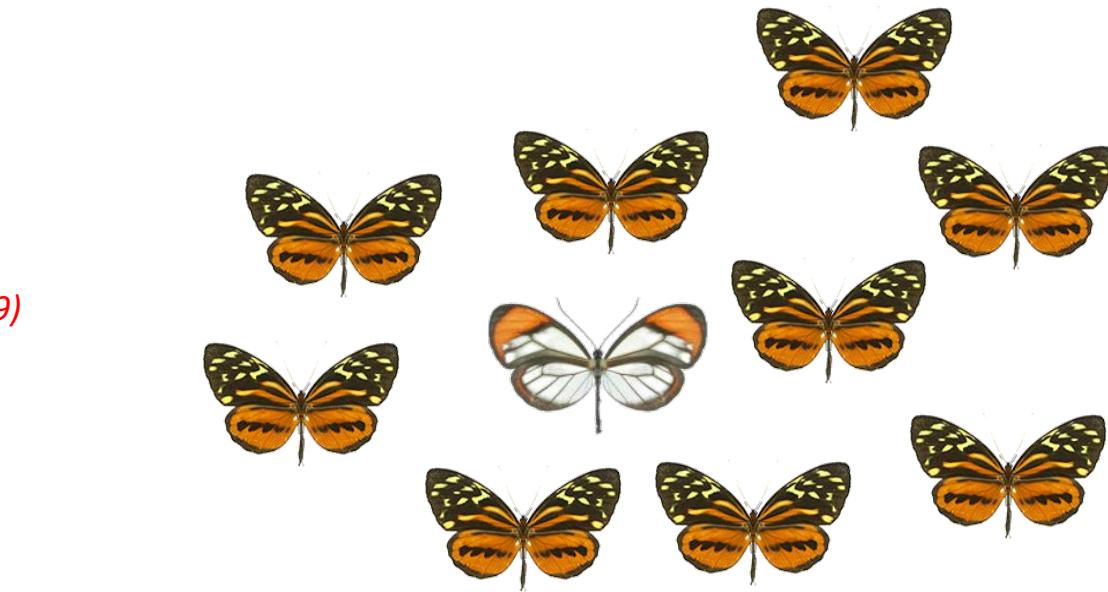
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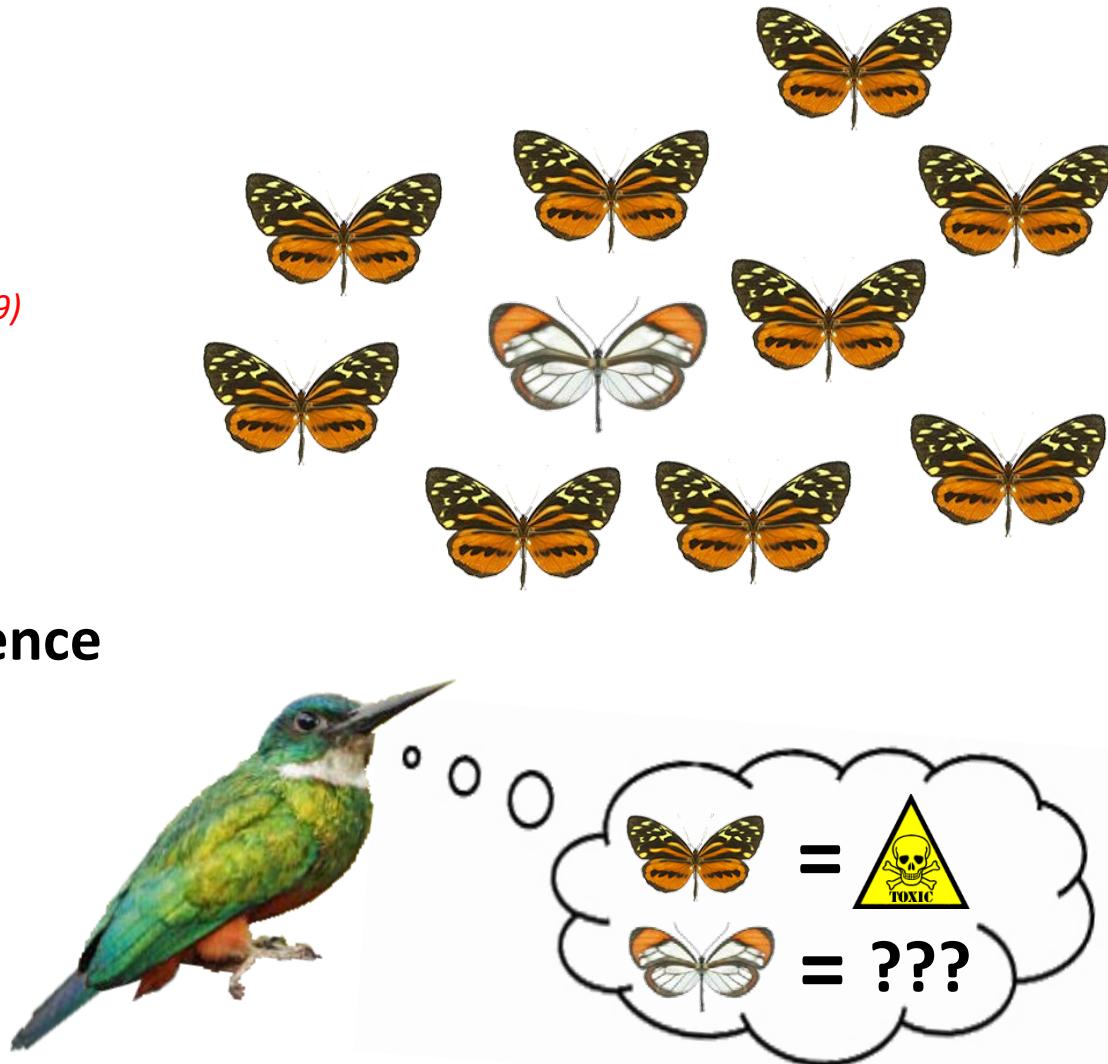
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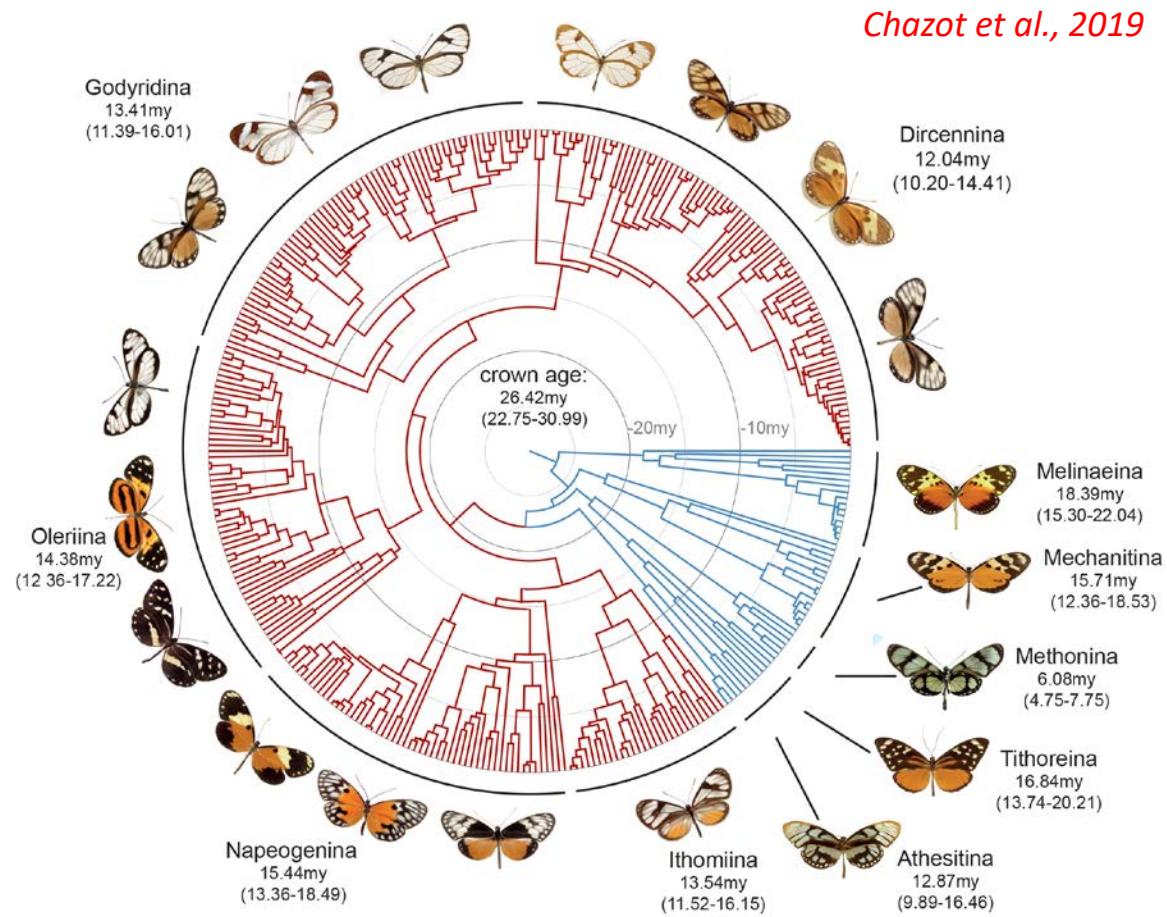
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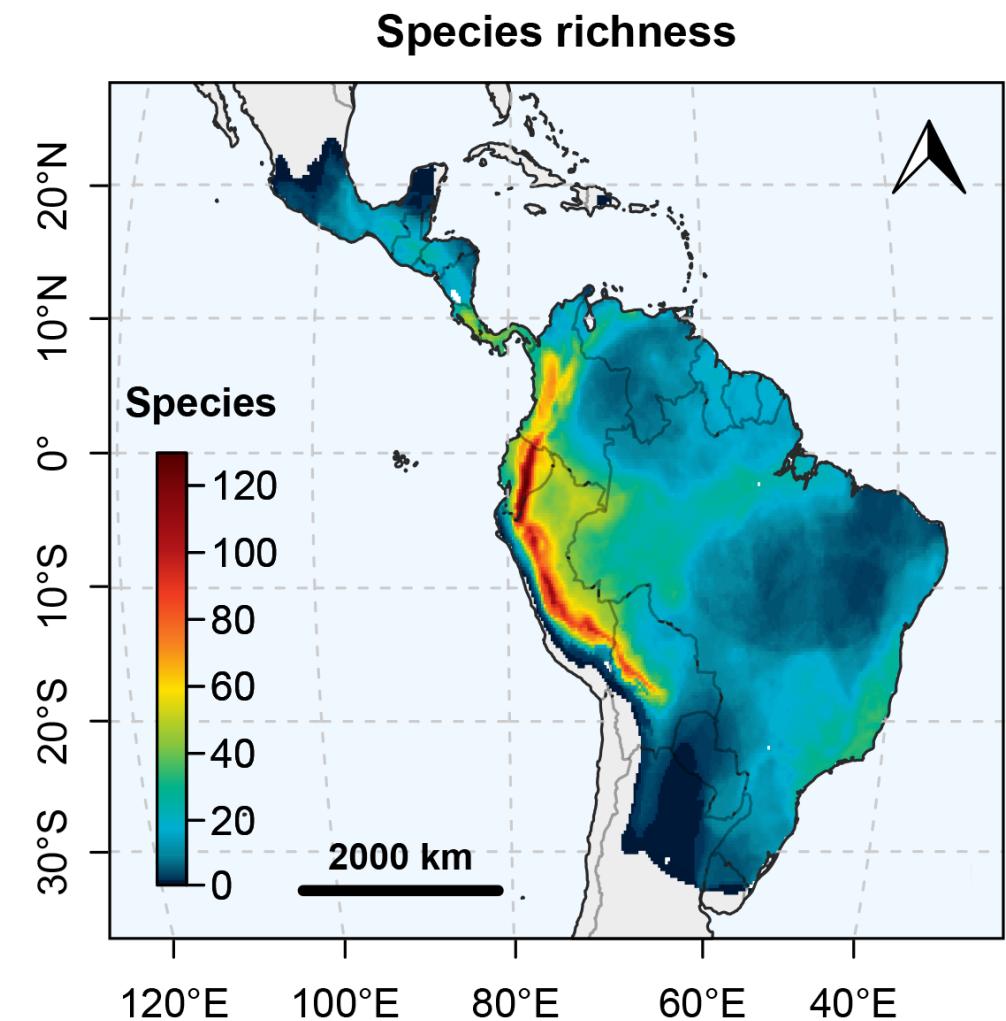
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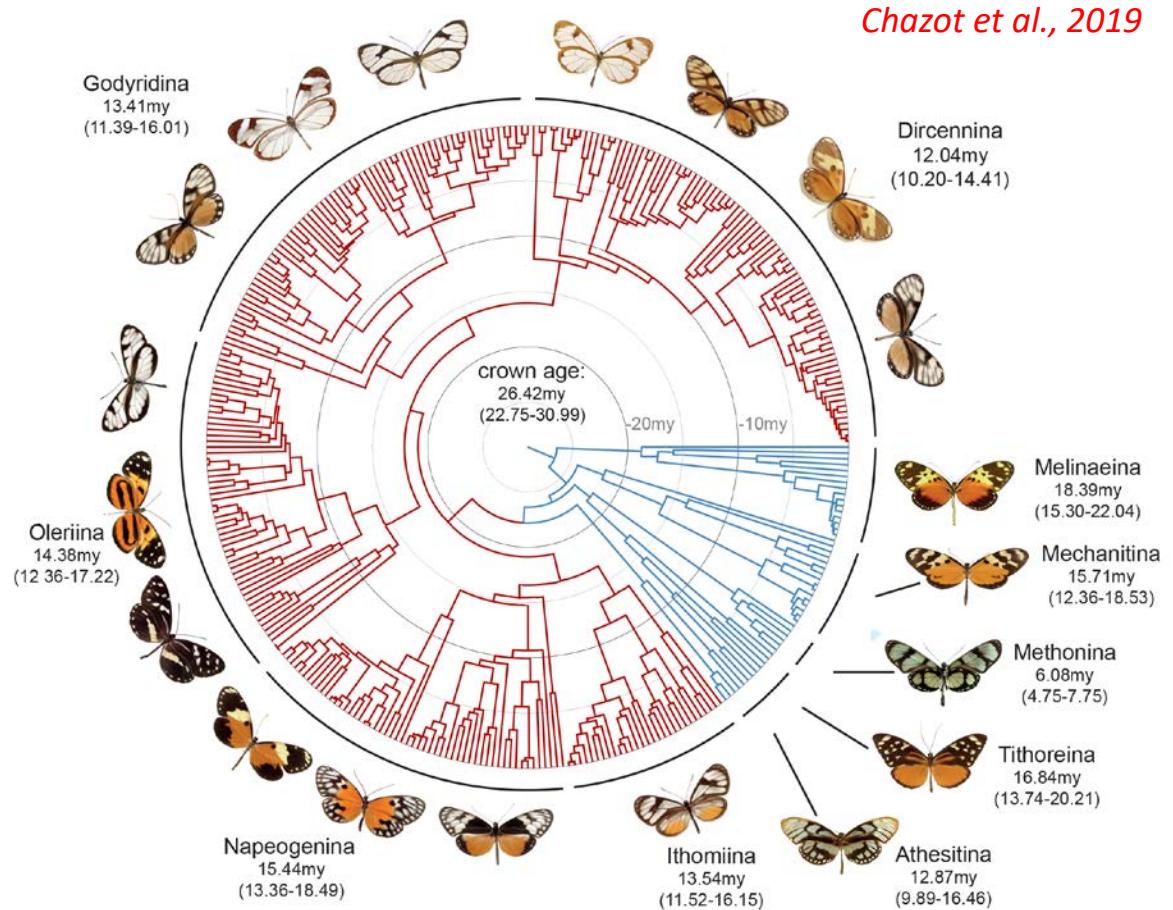
Study system: Ithomiini tribe



Adaptative radiation: 393 species in 25 My



Study system: Ithomiini tribe



Chazot et al., 2019

Credits: Nicolas Chazot



Adaptative radiation: 393 species in 25 My

44 mimicry rings (*sensu* K. Willmott)

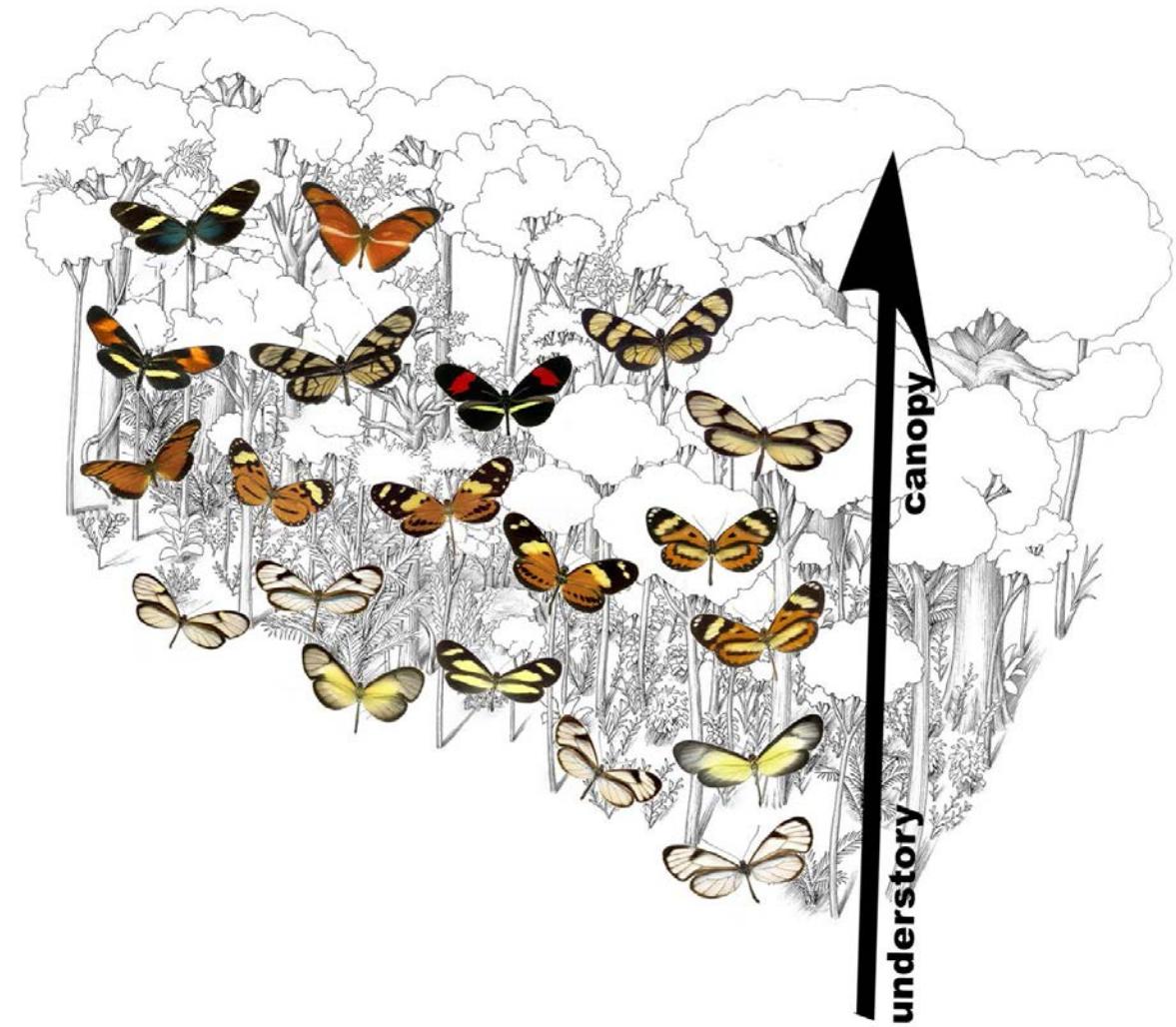
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Structuration of mimetic communities by:

- **flight height** (*Beccaloni, 1997*)
- **microhabitats** (*Elias et al., 2008*)
- **host plants** (*Willmott & Mallet, 2004*)
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Limits :

- **Spatial:** local to regional
- **Taxonomic:** few genera



Adapted from Birskis-Baros et al., 2021

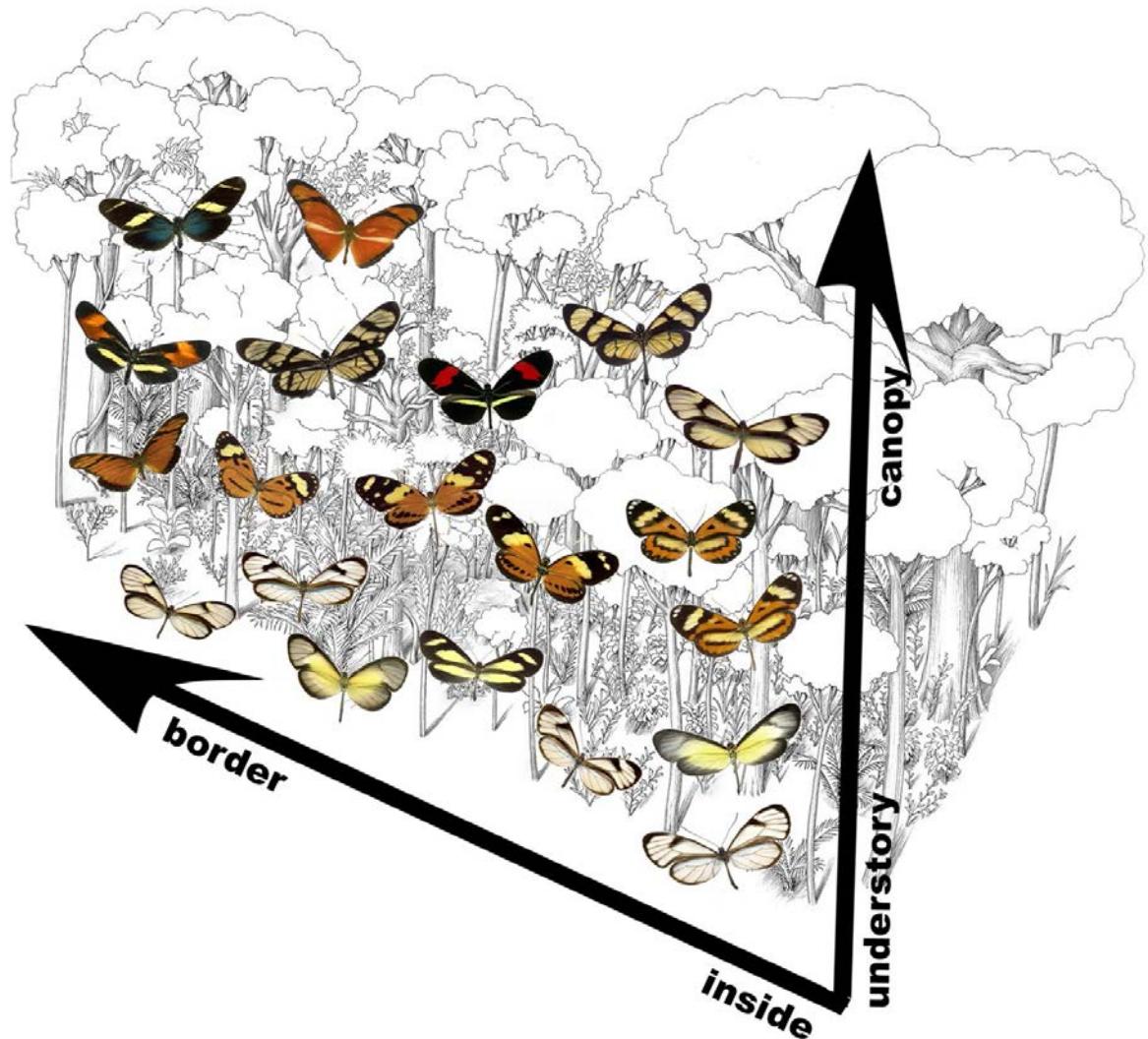
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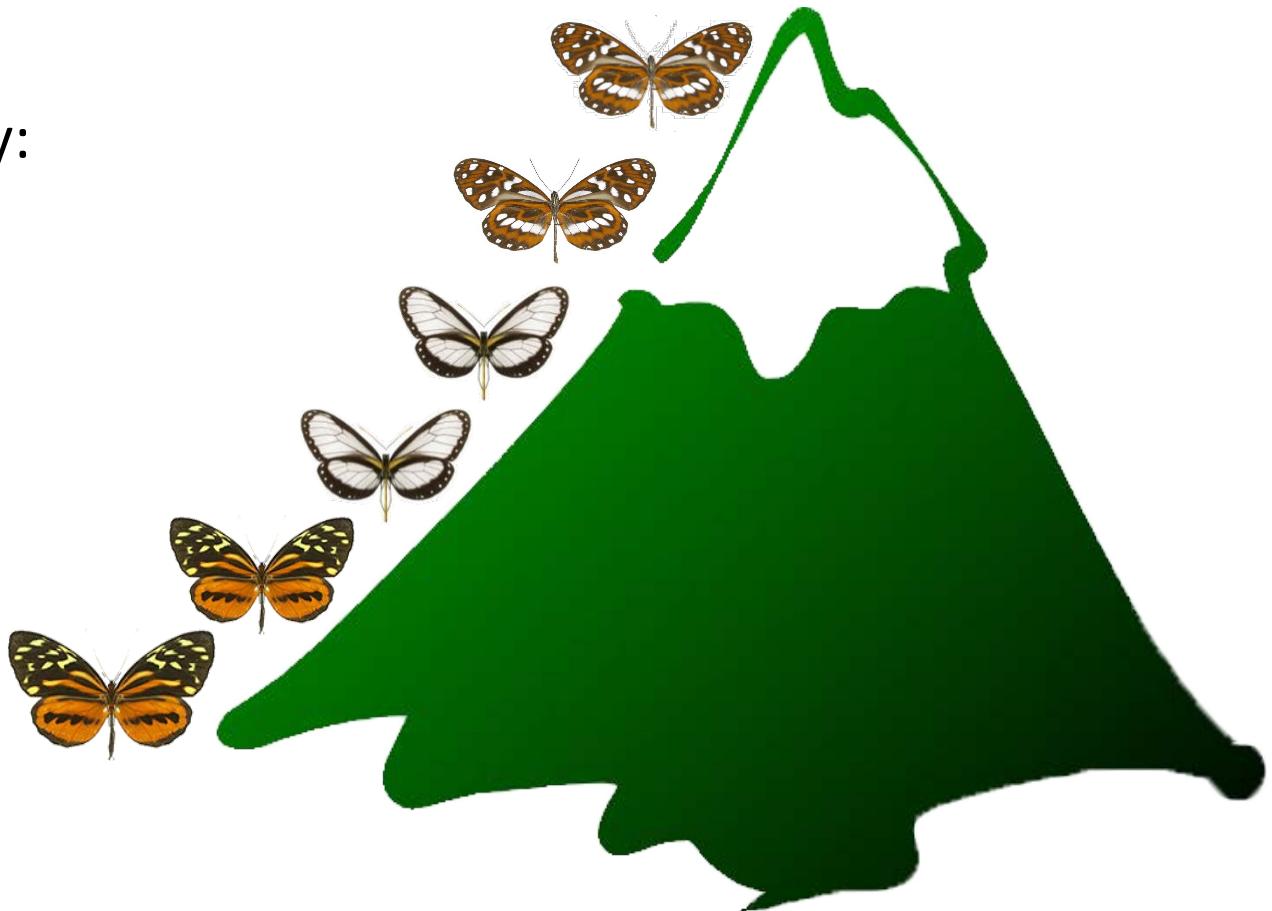
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This study: macroecological scale for the complete tribe
Dimensions = climatic niche

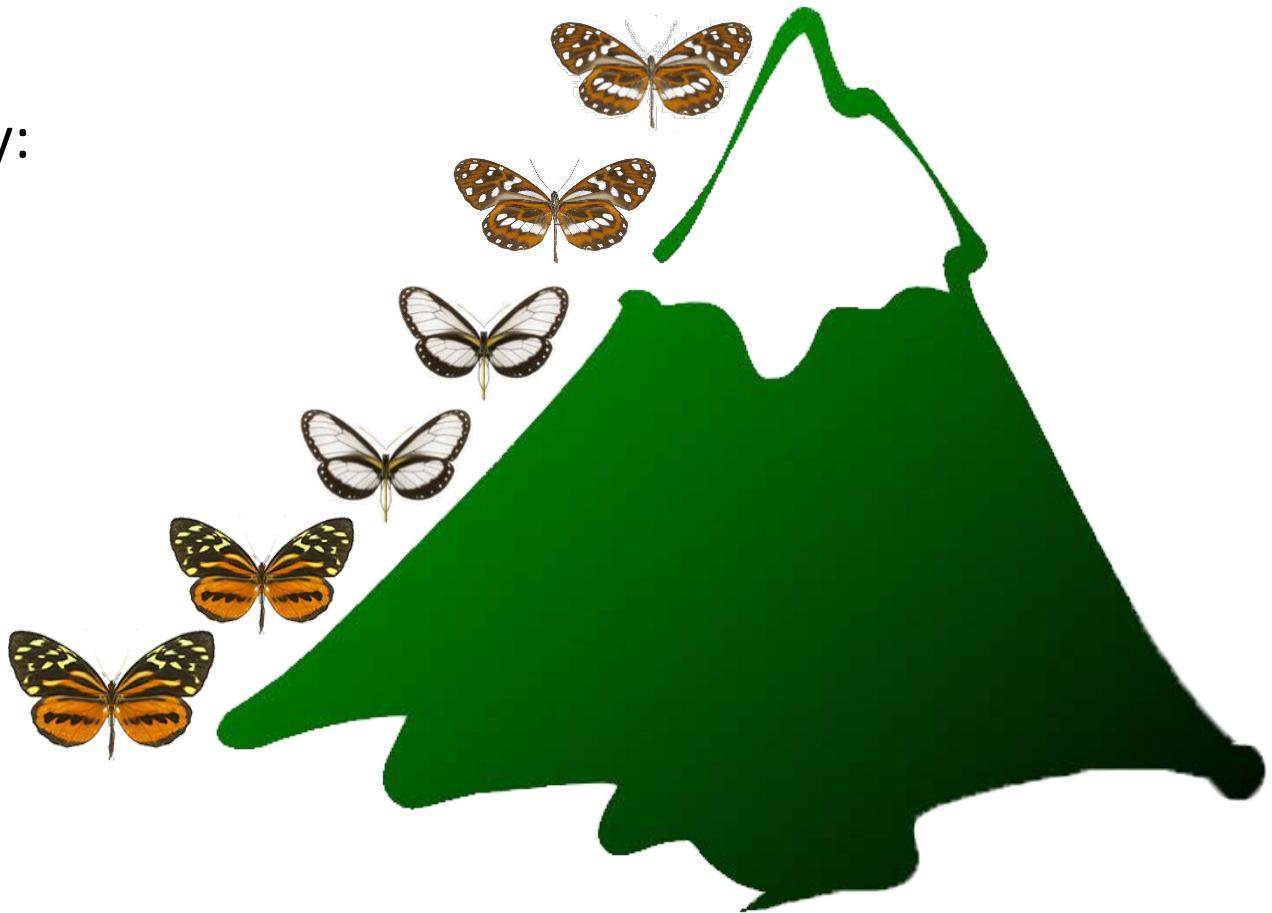
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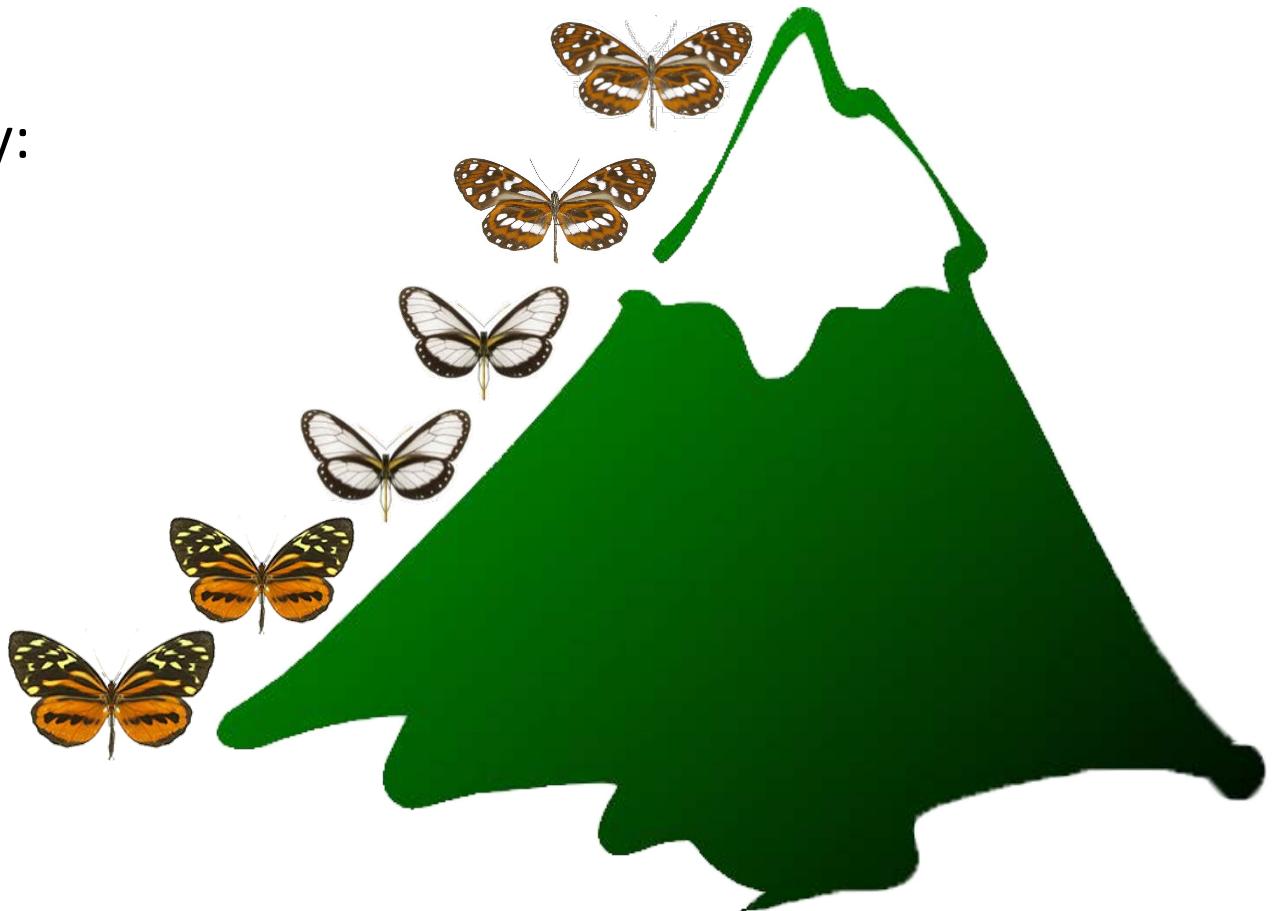
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This study: **macroecological scale for the complete tribe**
Dimensions = climatic niche

Objectives

Can **intraguild positive interactions** outweigh the effects of **competition** at the **macroecological scale**?



Community structure:

Do comimetic species **cooccur** more than expected at **random**?



Climatic niche evolution:

Is the **climatic niche** of comimetic species more similar than expected from **shared ancestry**?



Credits: E. Pérochon

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1

Community structure:

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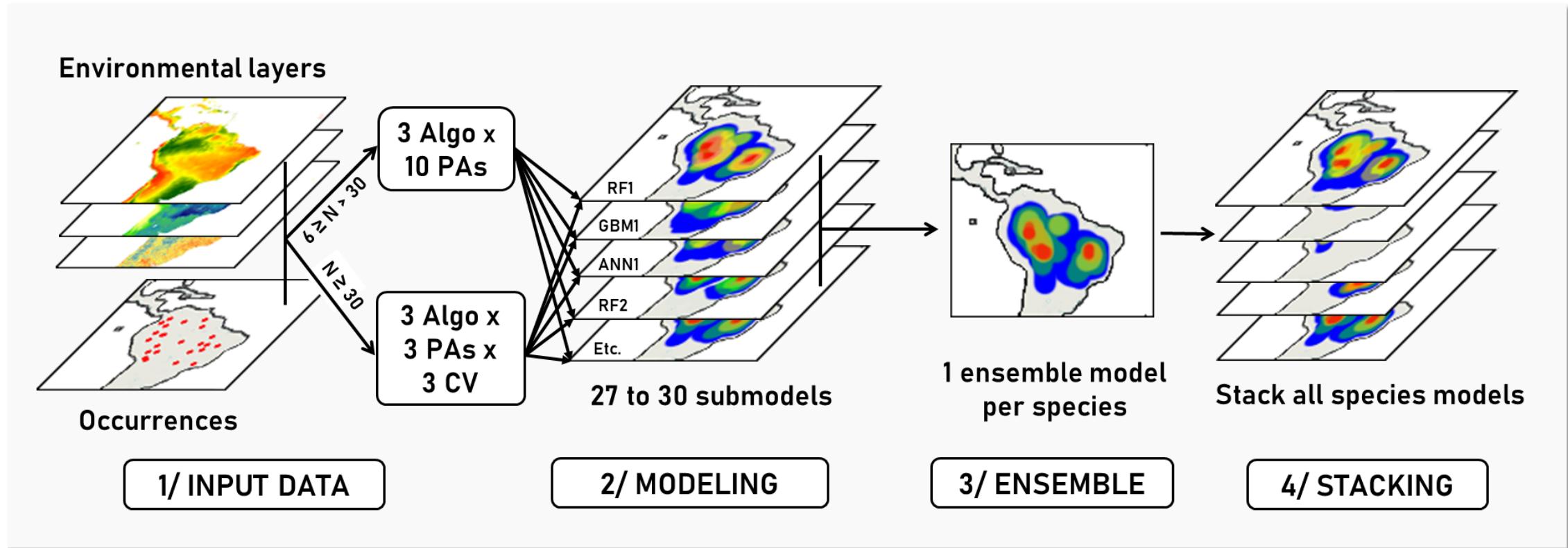
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Species Distribution Models



SDM → Species distribution maps → Community composition

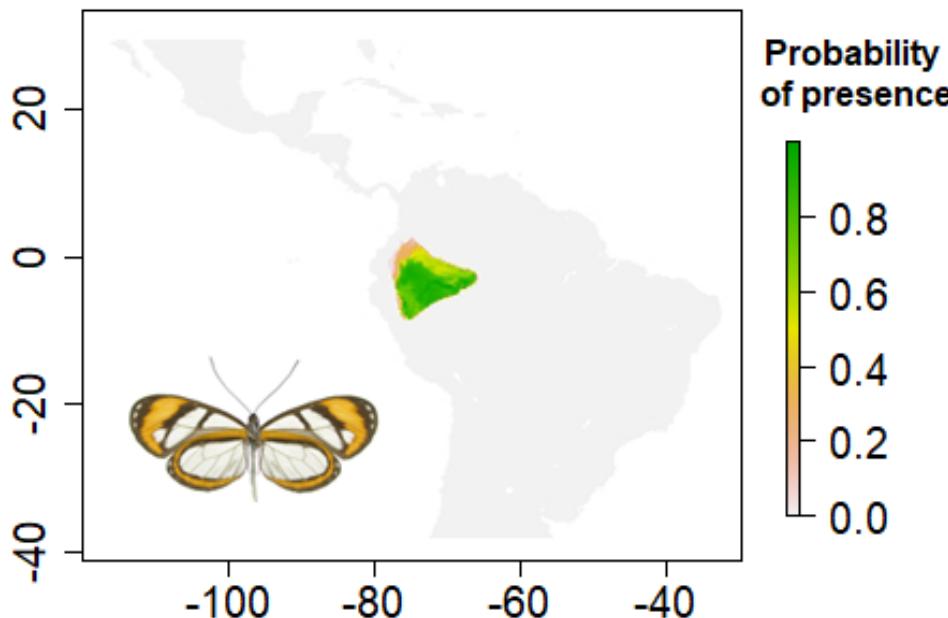
Community structure

Question: Do comimetic species **cooccur** more than expected at **random**?

Hypothesis: Lower **spatial dissimilarity** for comimetic species

$$BC_{ij} = 1 - \frac{2 \sum \min(P_i, P_j)}{\sum P_i + P_j}$$

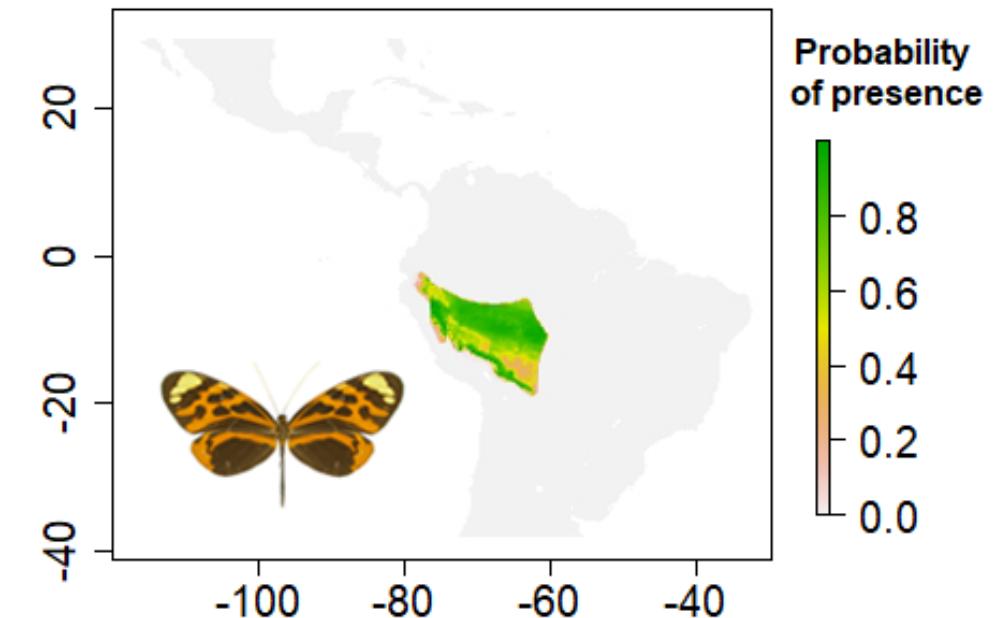
Hypoleria aureliana (AURELIANA)



No mimicry

BC = 0.9

Hypothisis cantabrica (MAMERCUS)



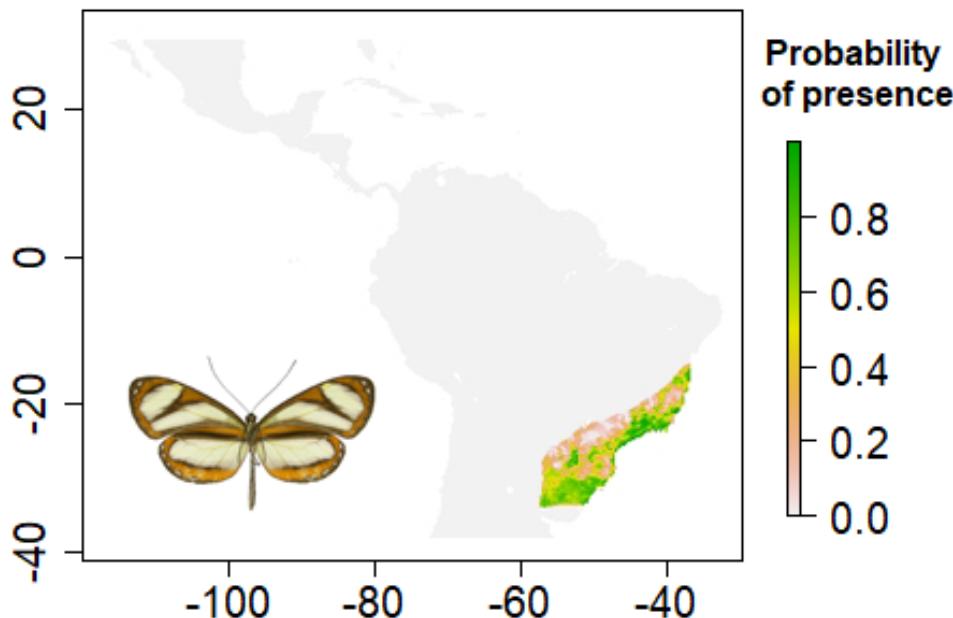
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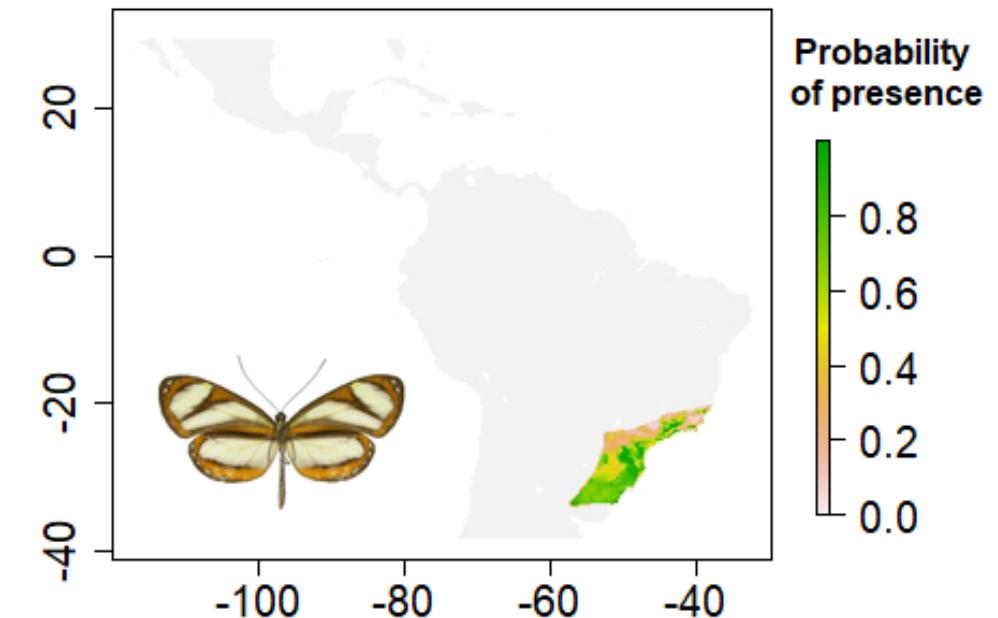
Epityches eupompe (EURIMEDIA)



Mimicry

BC = 0.2

Episcada philoclea (EURIMEDIA)



Community structure

Question: Do comimetic species **cooccur** more than expected at **random**?

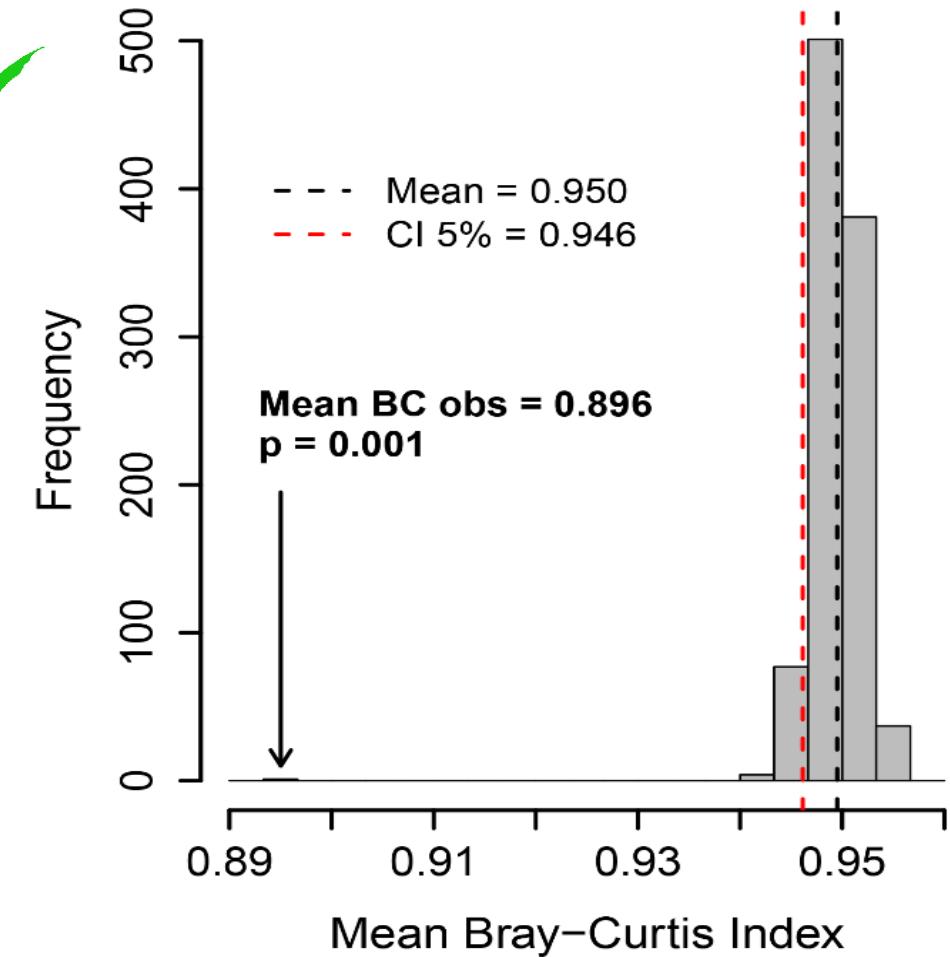
Global: Mean BC_{obs} << Mean BC_{perm} ; $p = 0.001$



Per ring: 33 out of 39 rings (85%)

- Non-significant rings = low N

Next: Is this pattern of cooccurrence strengthened by climatic niche similarity across comimics?



Community structure

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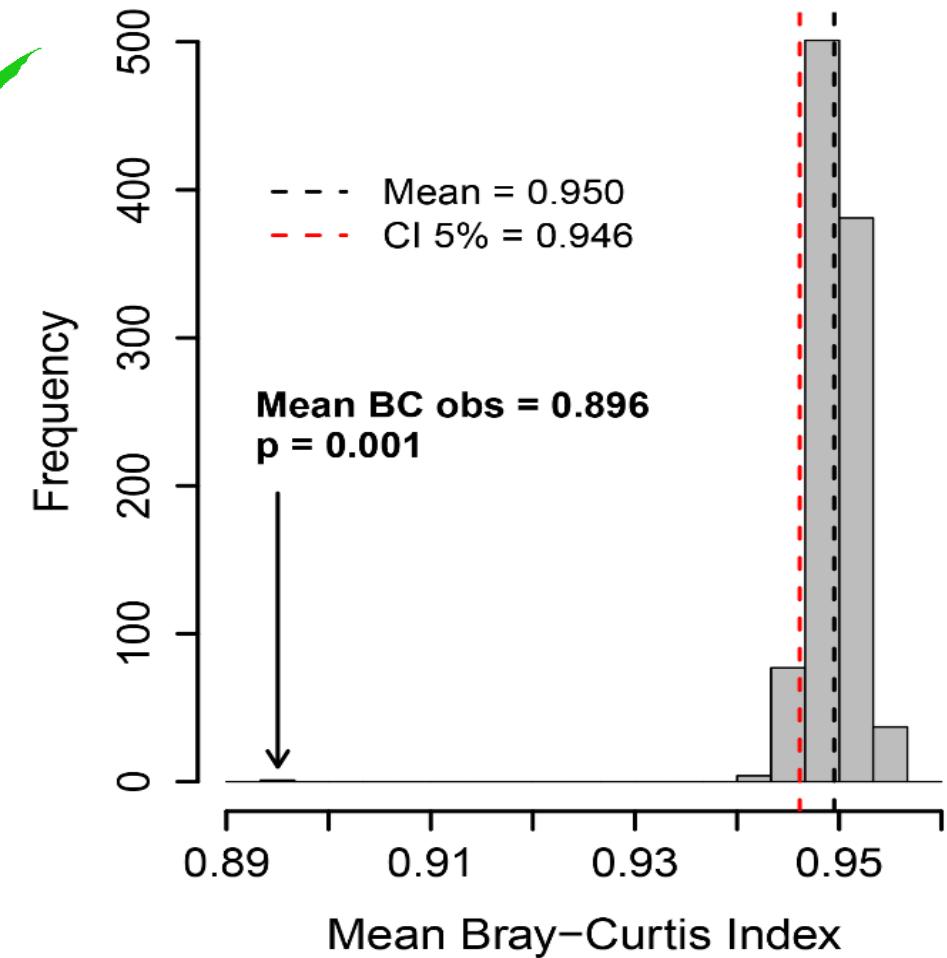
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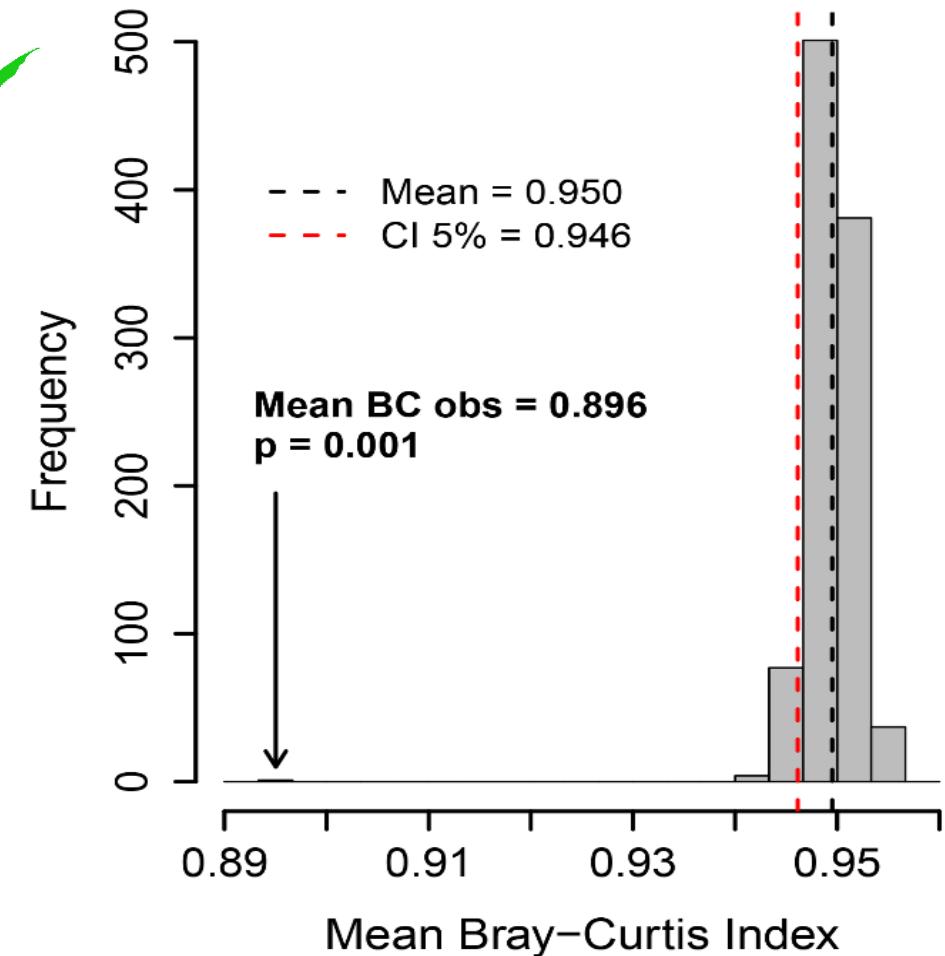
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Climatic niche similarity

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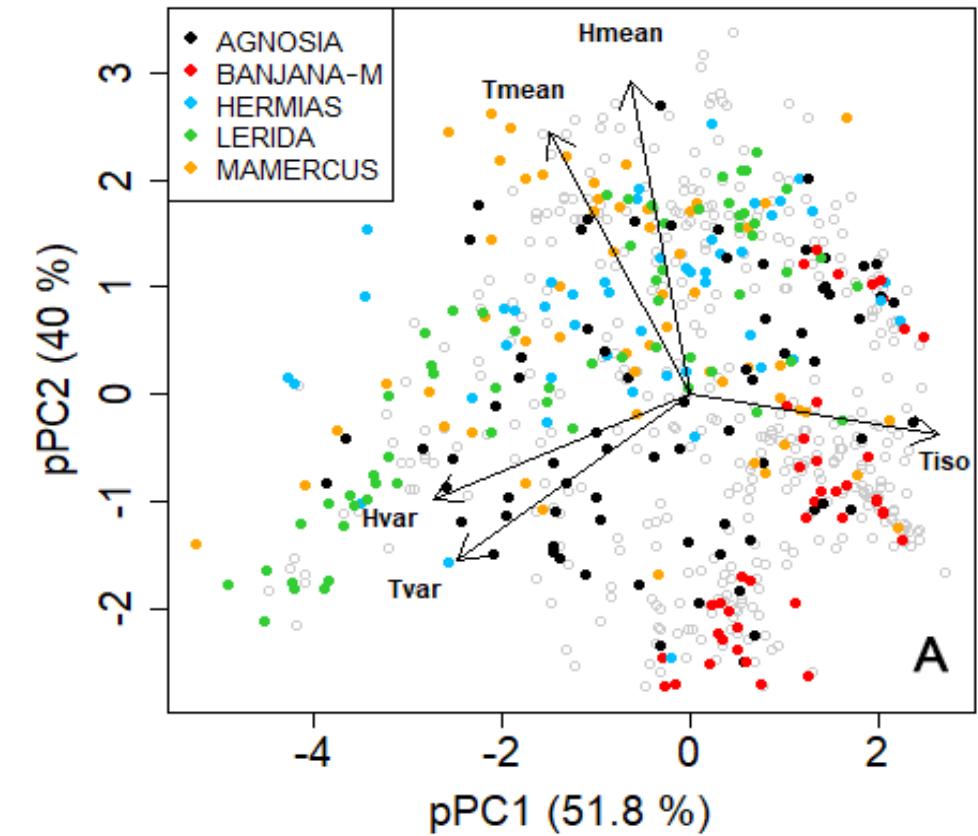
Global: perMANOVA, $R^2 = 0.41$, $p = 0.001$



Per ring:

- 205 pairs out of 253 (81.0%) with $p < 0.05$
- 168 pairs out of 253 (66.4%) with $p < 0.001$

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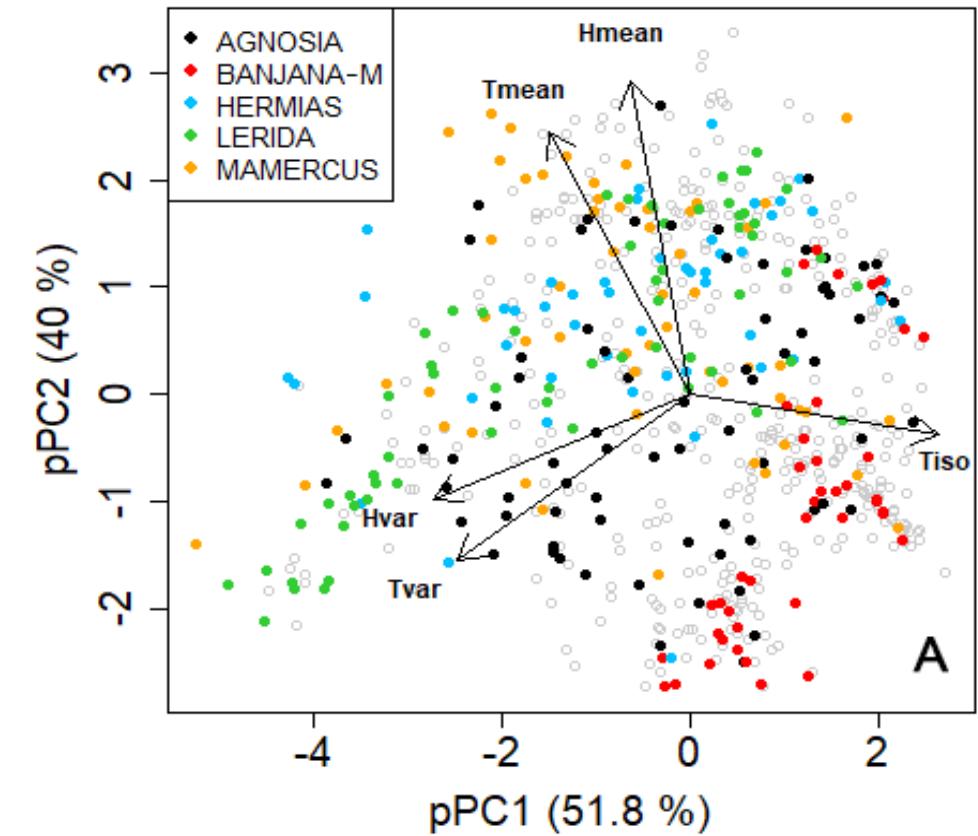
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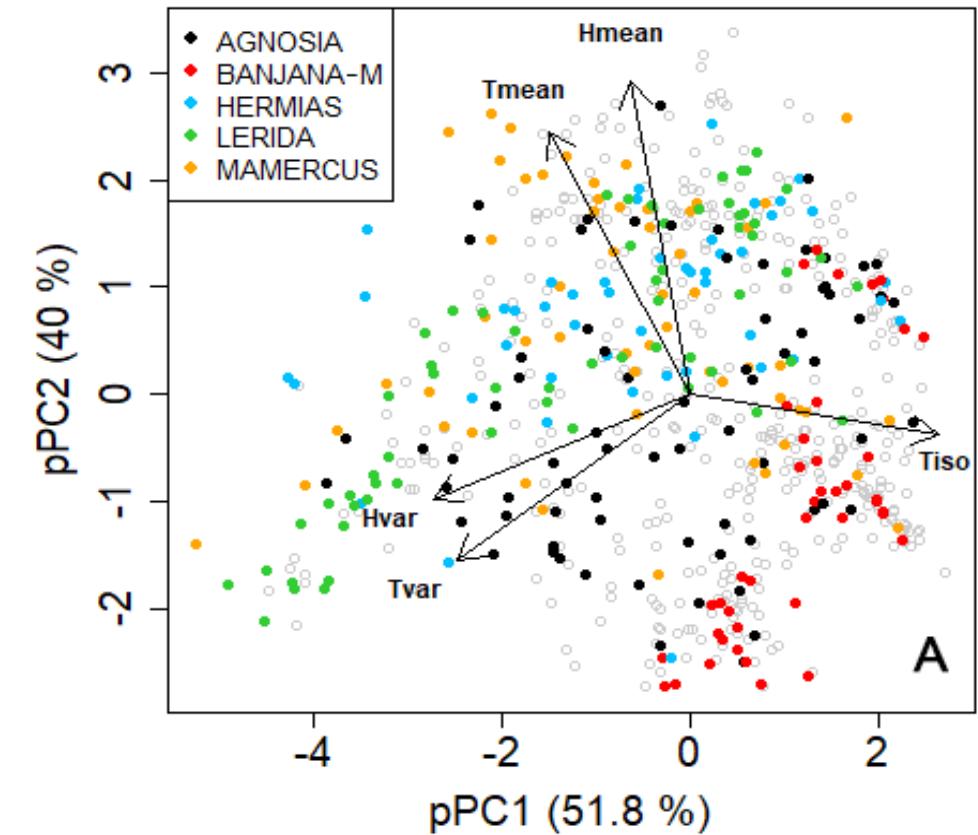
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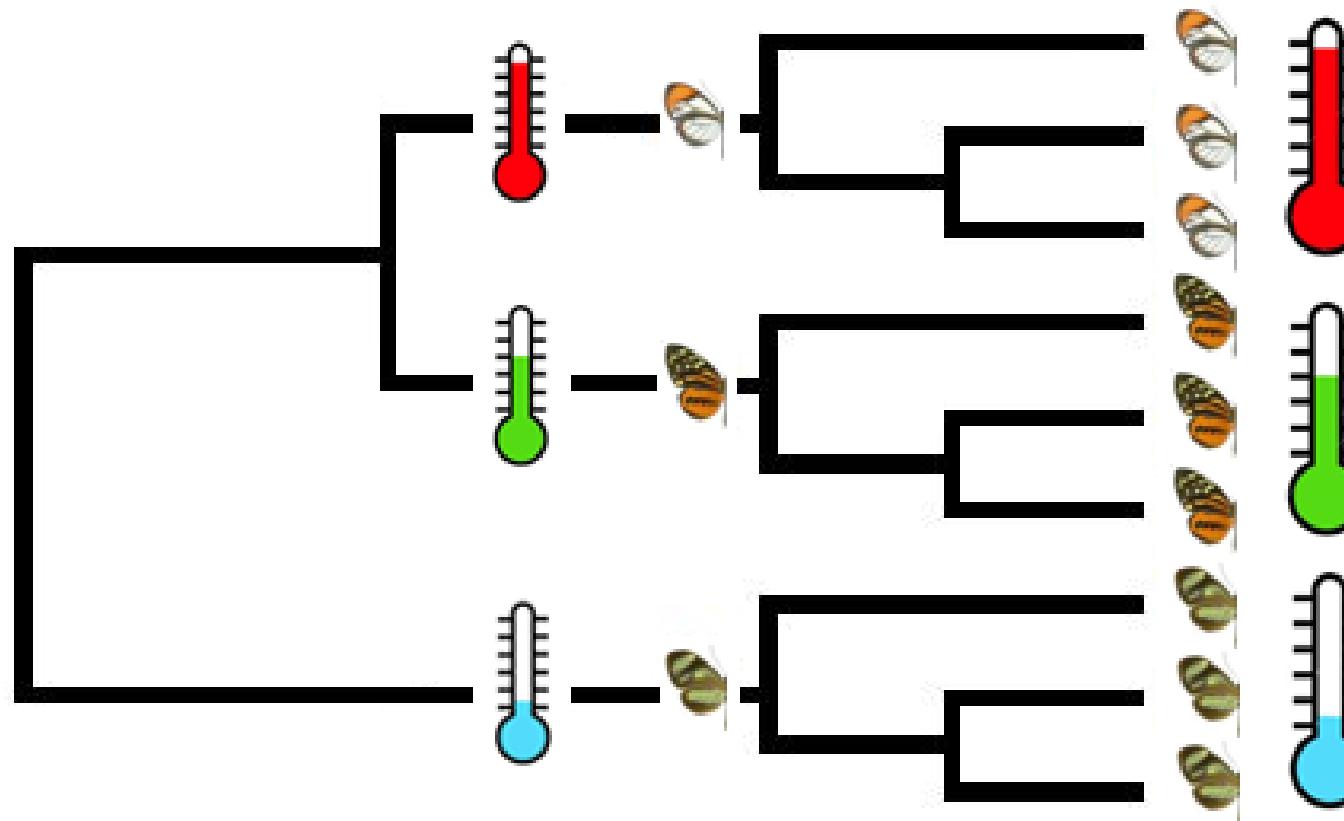
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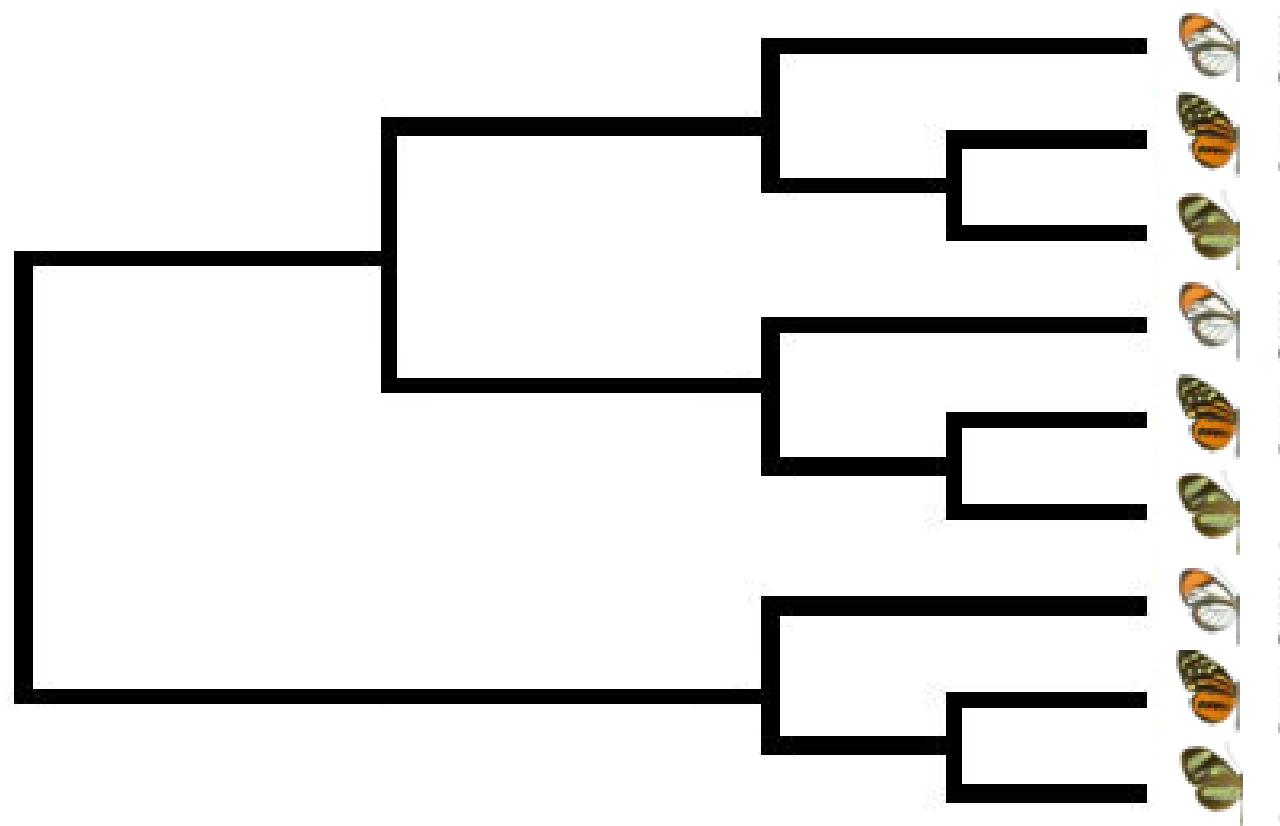
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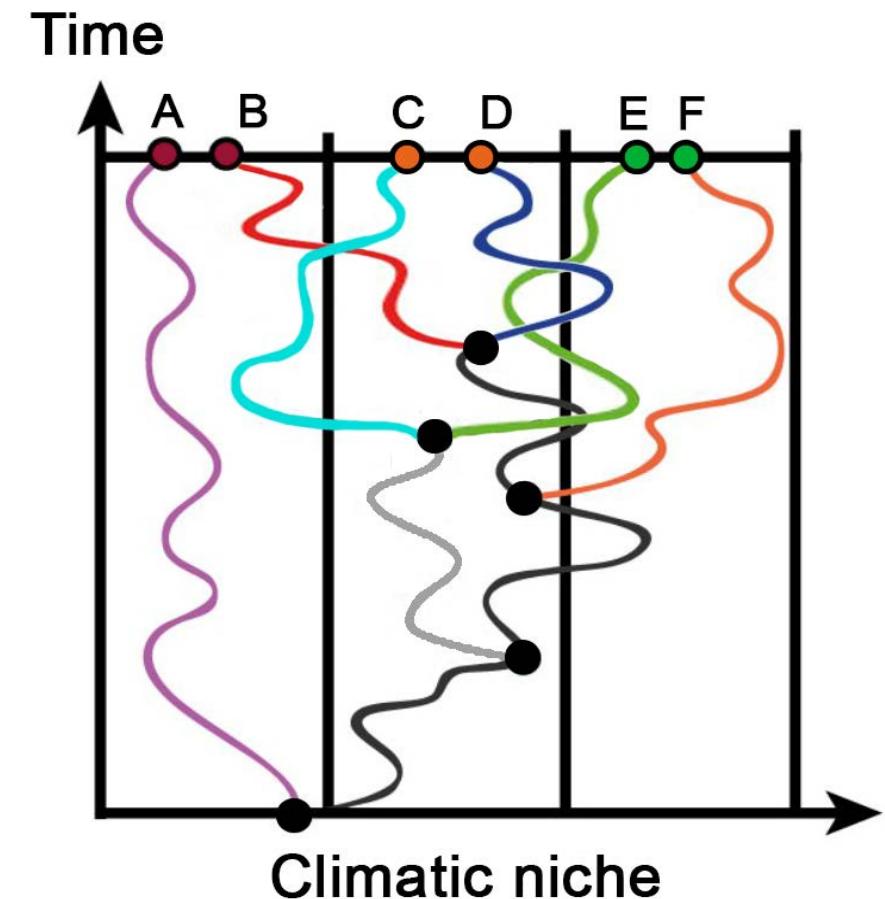
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Simulate the evolution of climatic niche under multivariate **neutral evolutionary model**

phyloMANOVA: $\lambda_{\text{obs}} \ll \lambda_{\text{simul}}$, $p = 0,001$

Conclusion:

- Evolutionary association between climatic niche and mimicry patterns
- Strengthens cooccurrence of comimics



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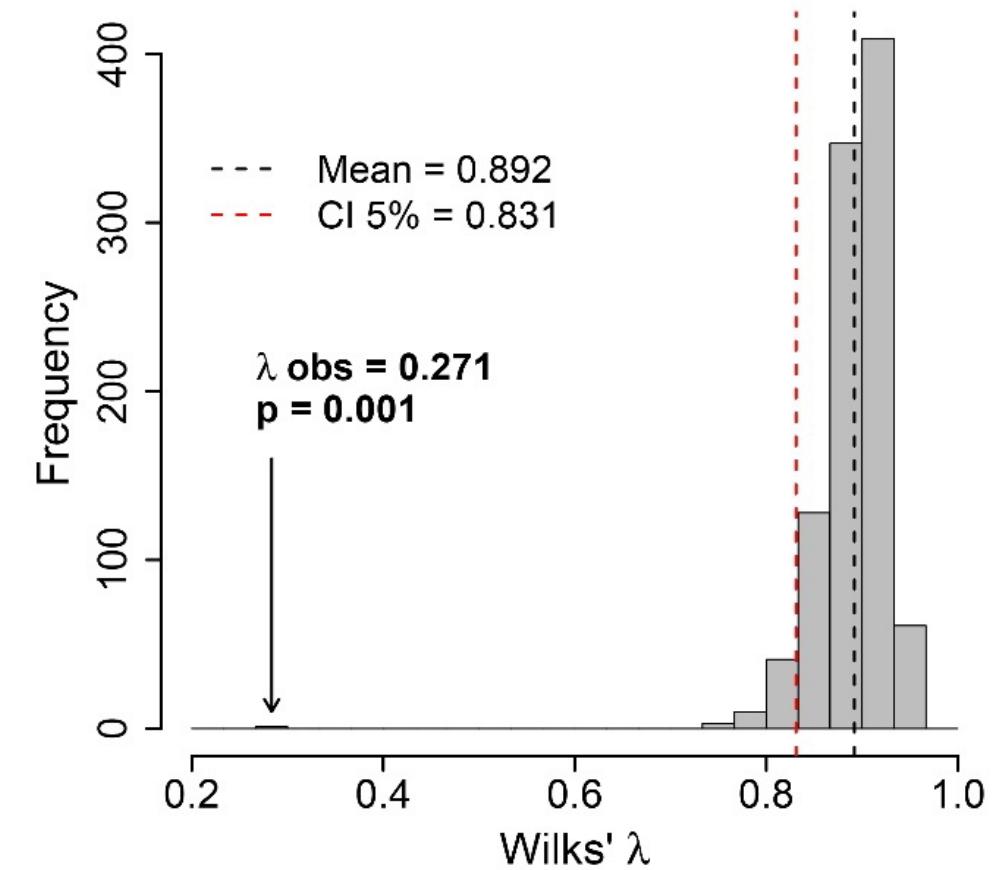
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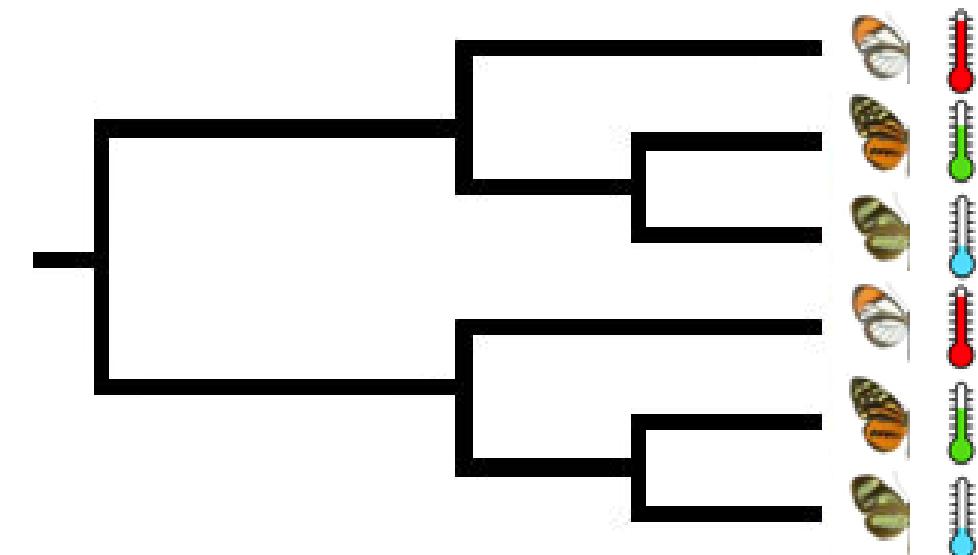


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Conclusion:

- **Evolutionary association** between **climatic niche** and **mimicry patterns**
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Mechanistic scenario

Observed pattern: climatic niche of comimetic species are more similar than expected from the **phylogeny**

Mechanism 1: Evolutionary convergence of **species niche** within mimicry rings?

(Gompert *et al.*, 2011)

Mechanism 2: Evolutionary convergence of mimicry patterns within species with similar niche and spatial distribution?

(Sherratt, 2008)

Realistic scenario: both!

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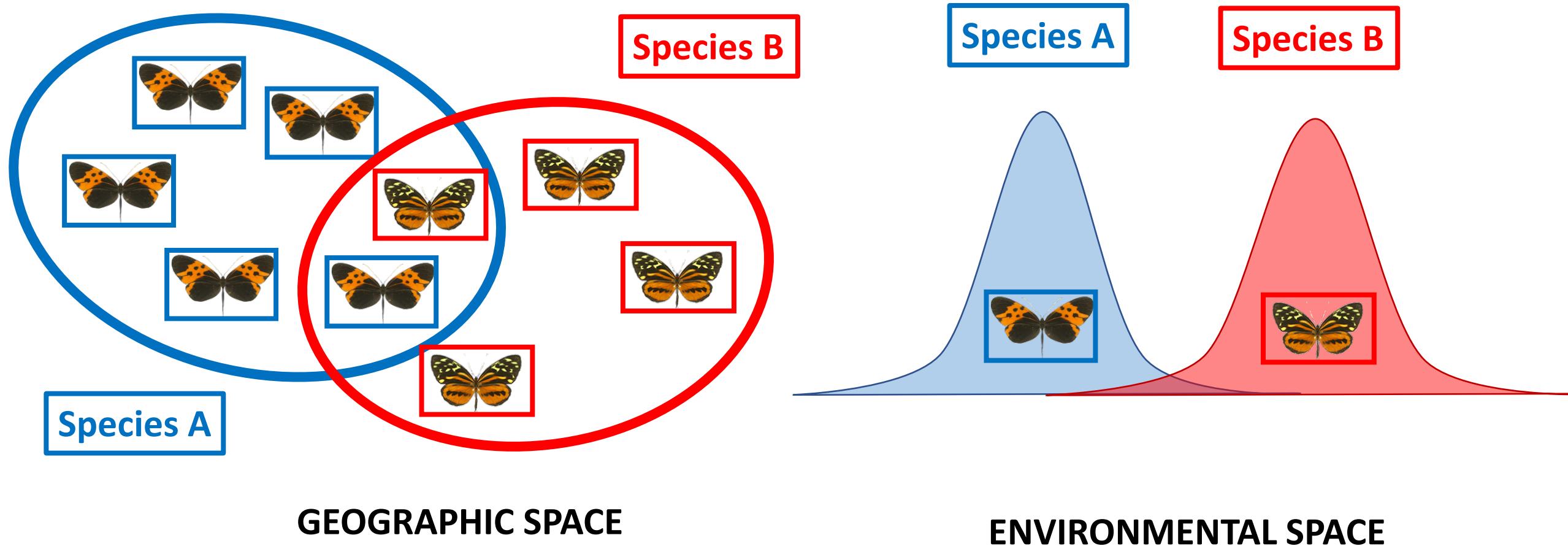
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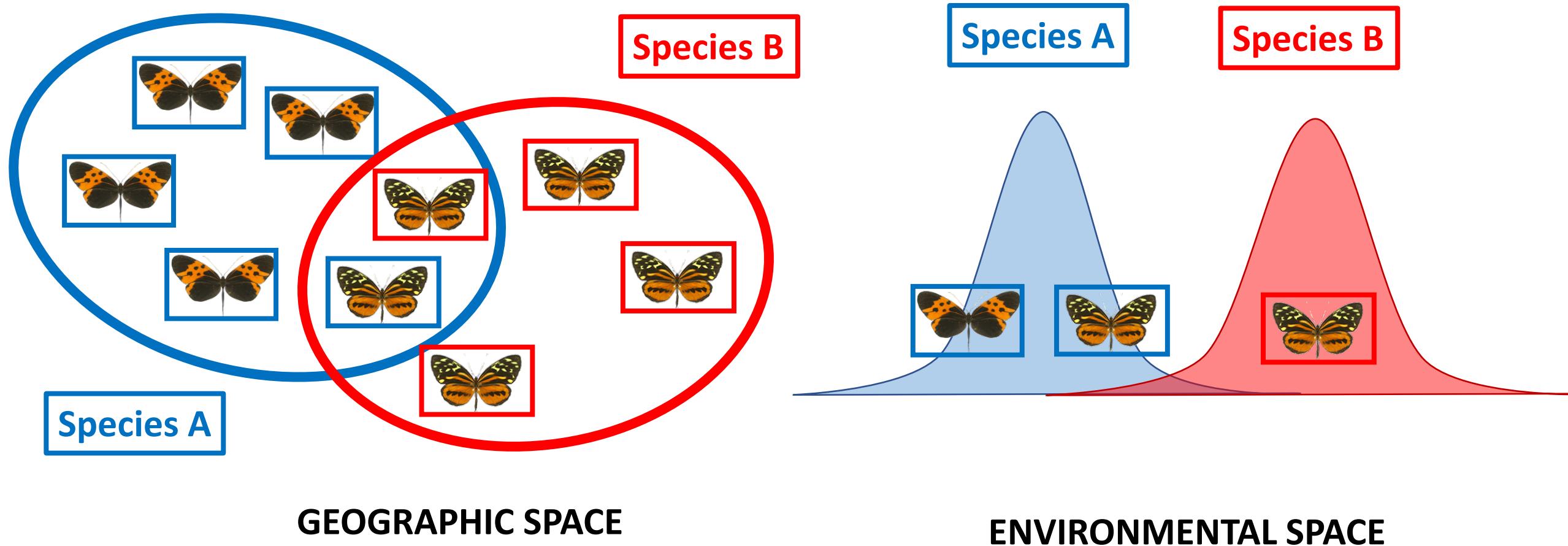
Mechanistic scenario

1/ Initial partial overlap



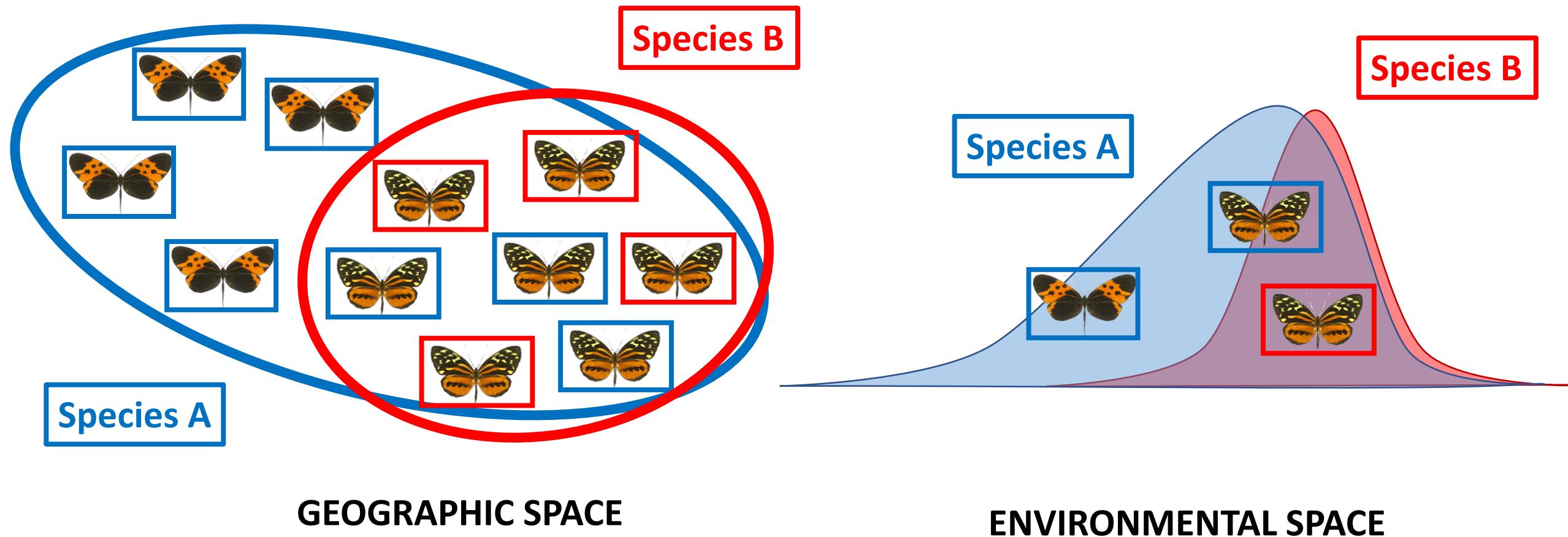
Mechanistic scenario

2/ Pattern convergence



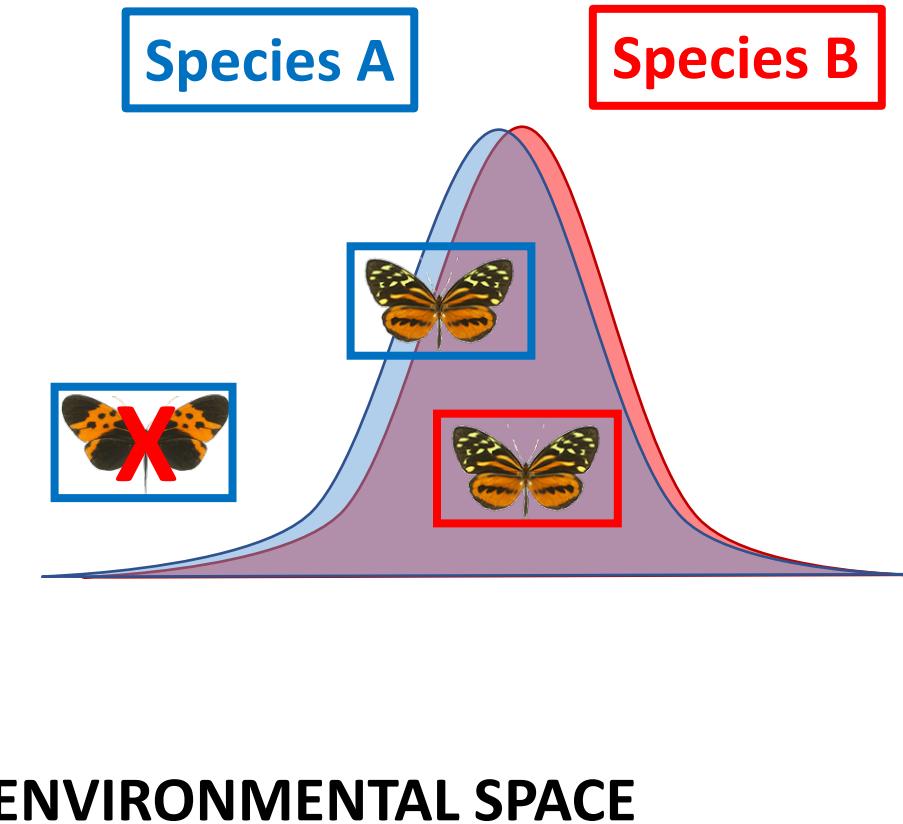
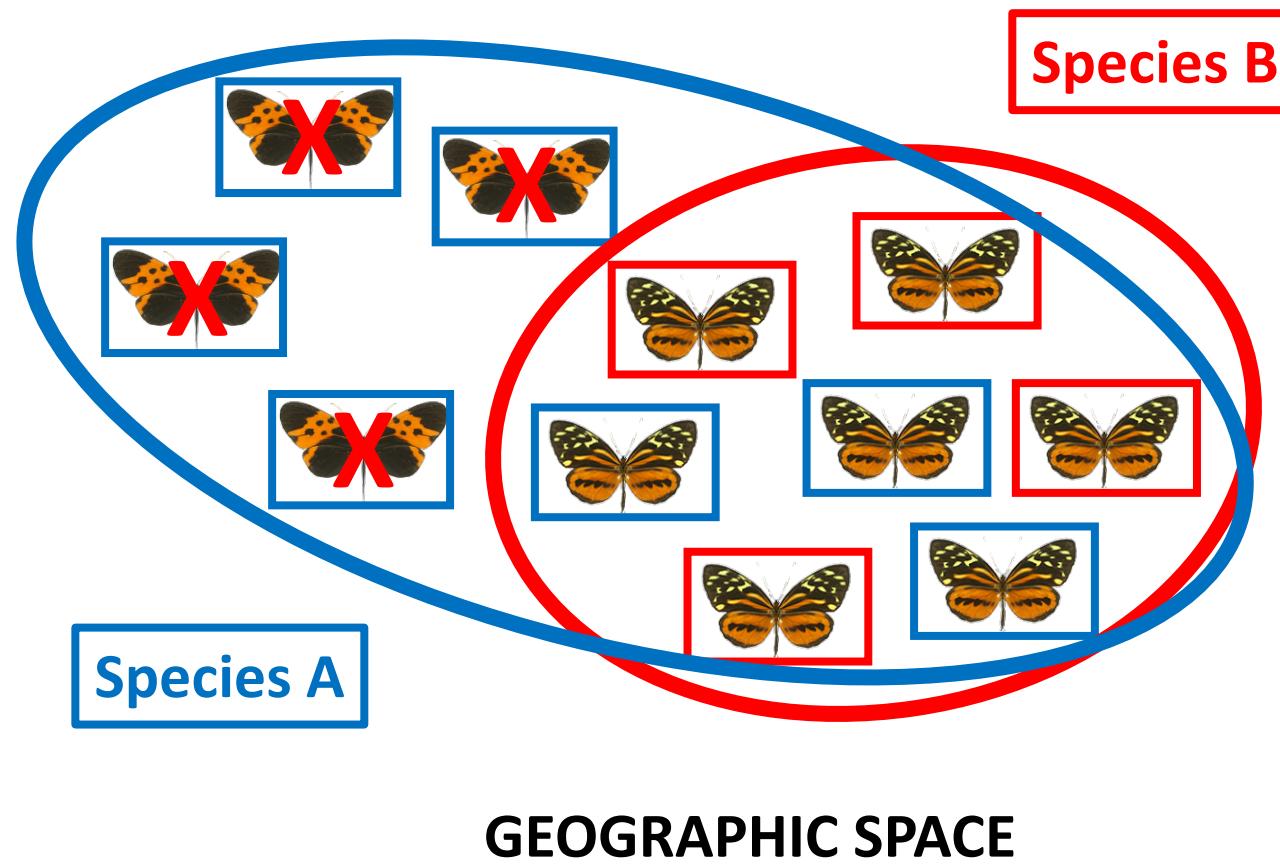
Mechanistic scenario

3/ Niche expansion



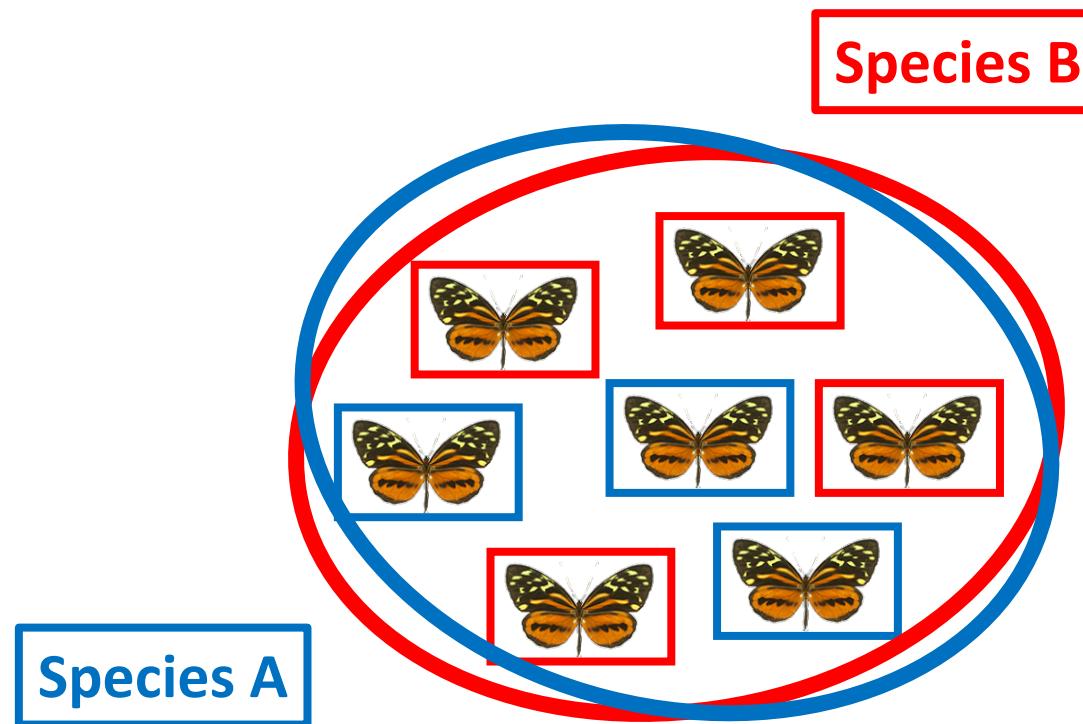
Mechanistic scenario

4/ Niche thinning

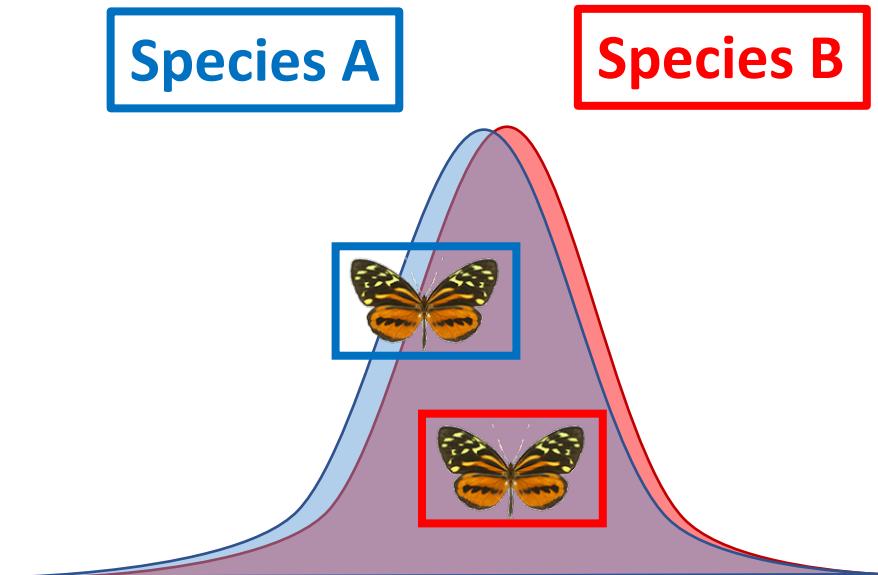


Mechanistic scenario

5/ Final overlap



GEOGRAPHIC SPACE



ENVIRONMENTAL SPACE

Perspectives

Mutualistic communities = **adaptive assemblage** of species (patterns + niche)

- Sensitivity to interaction disruption and **cascade of extinctions**

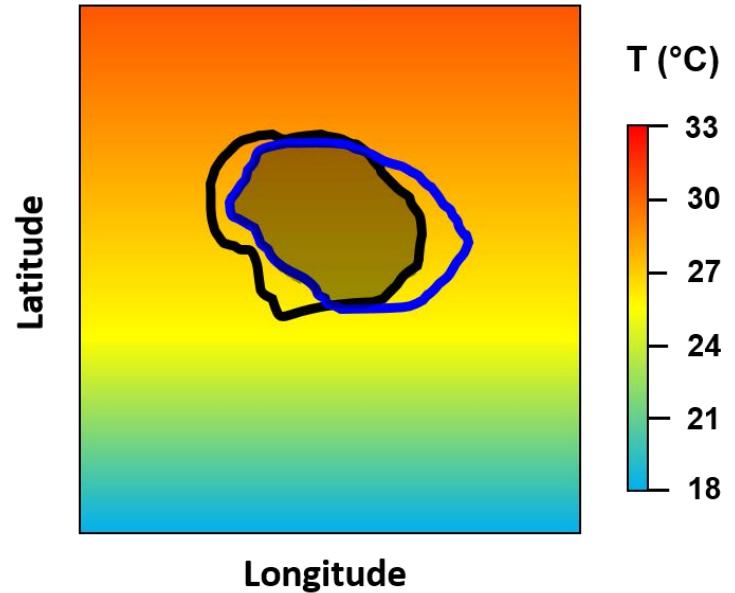
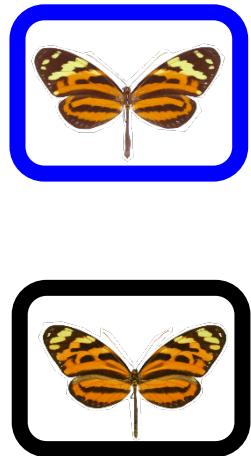
Which response to **climate change**?

Perspectives

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Cohesion?

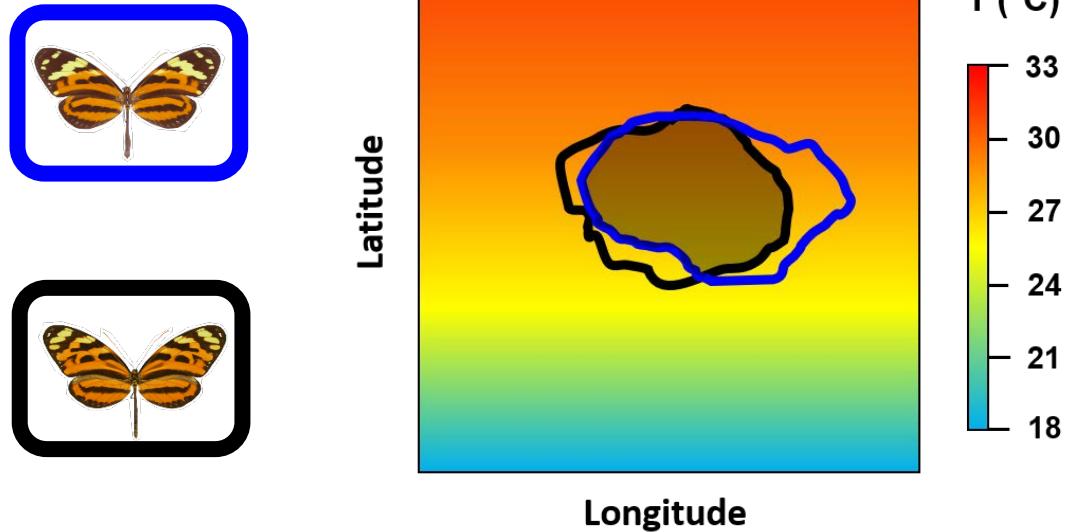


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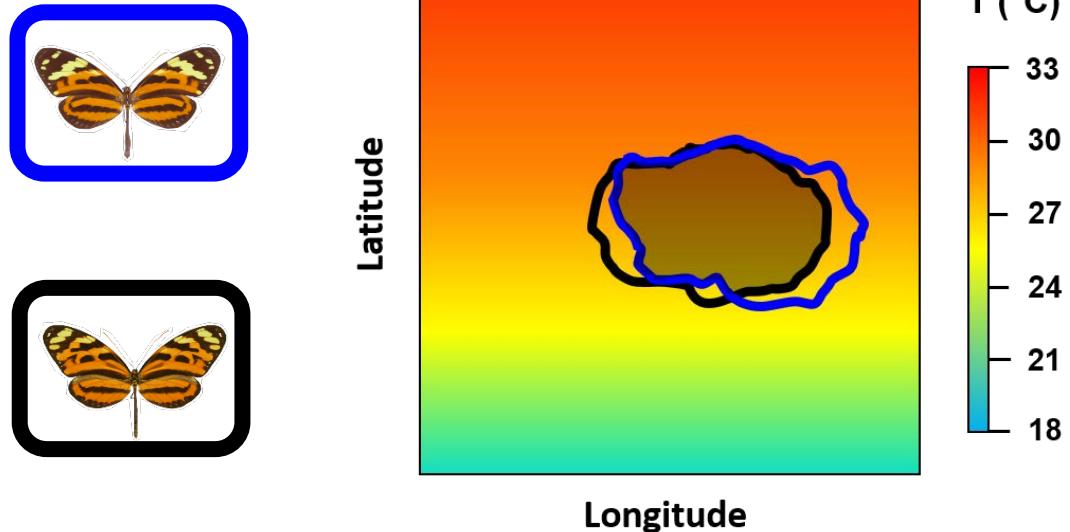


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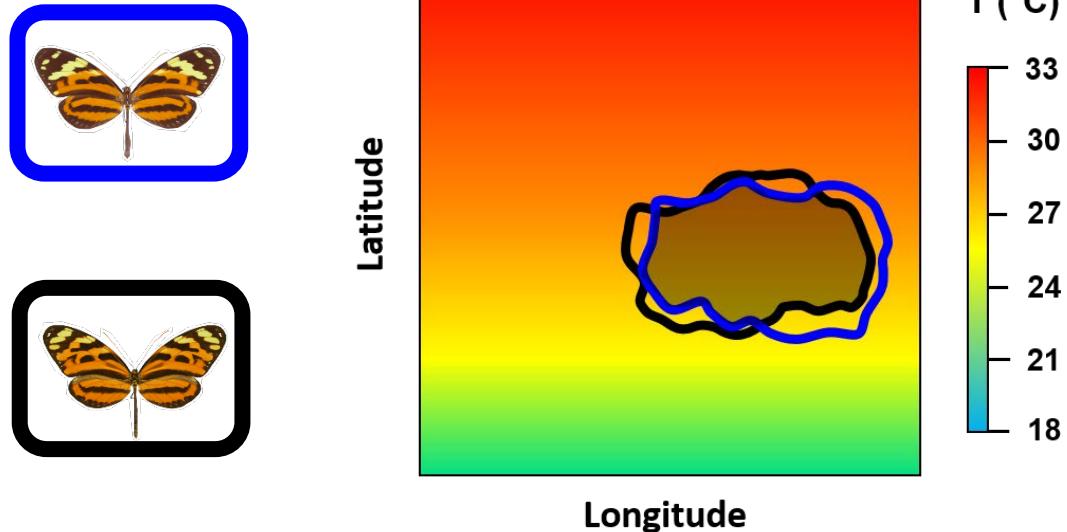


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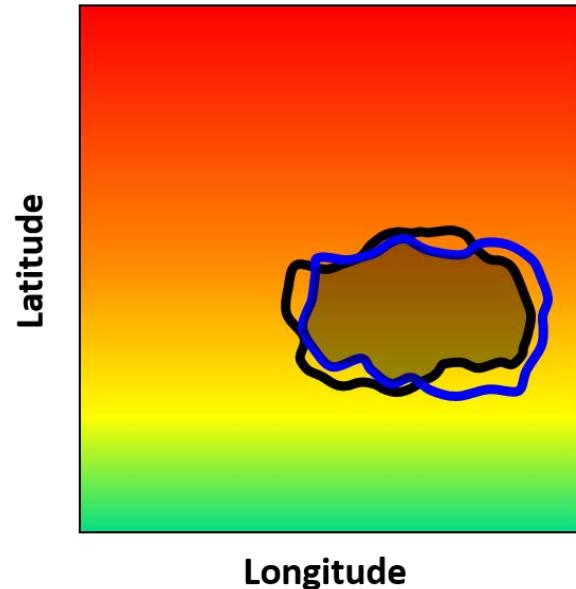
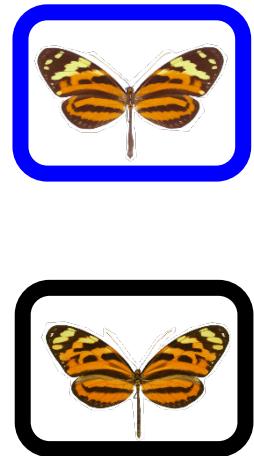


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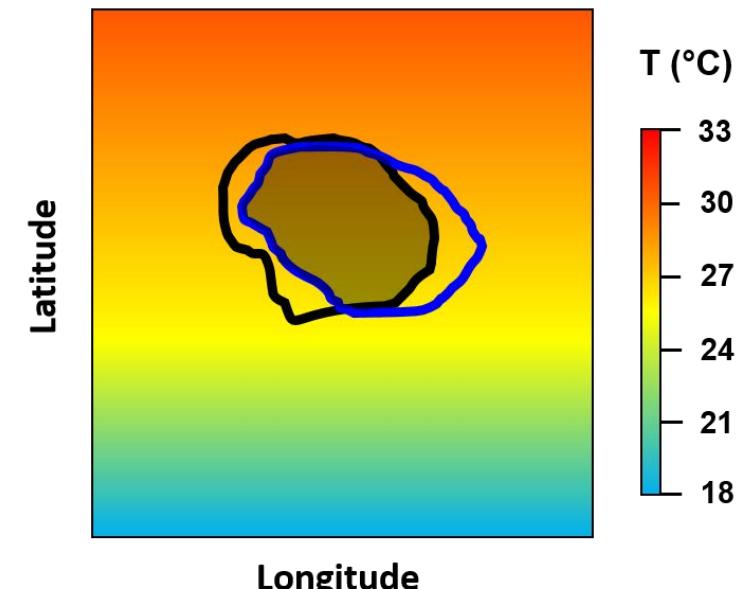
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Disassembly?

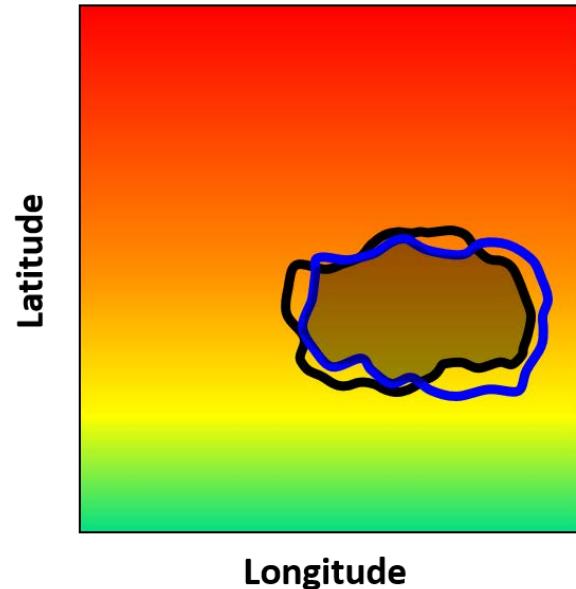
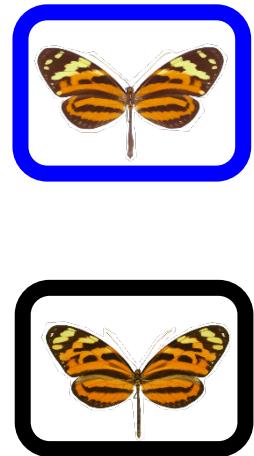


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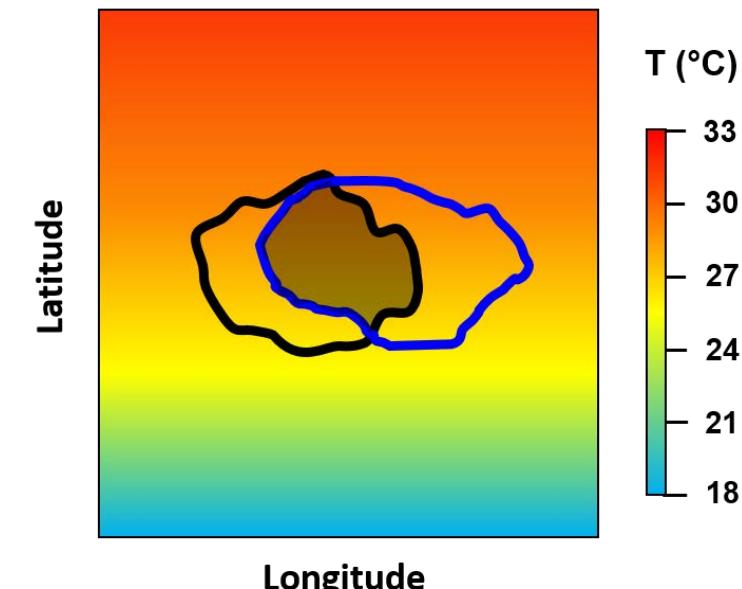
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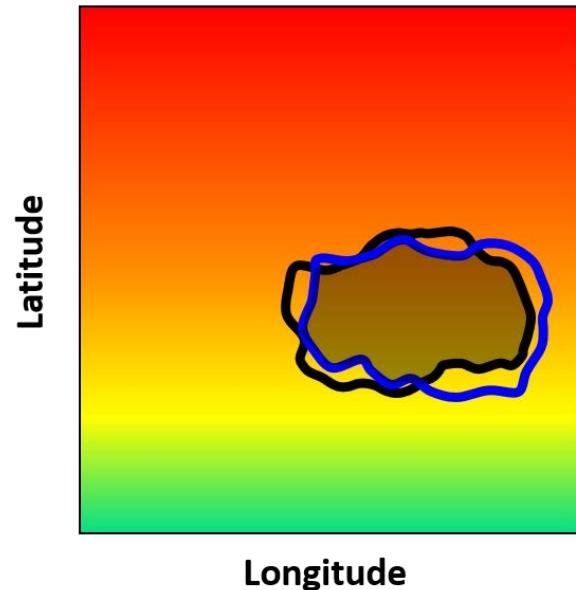
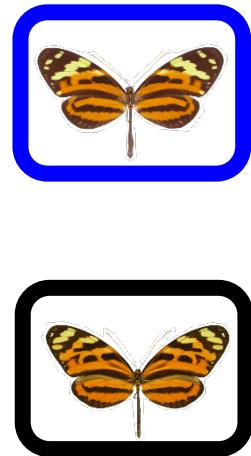


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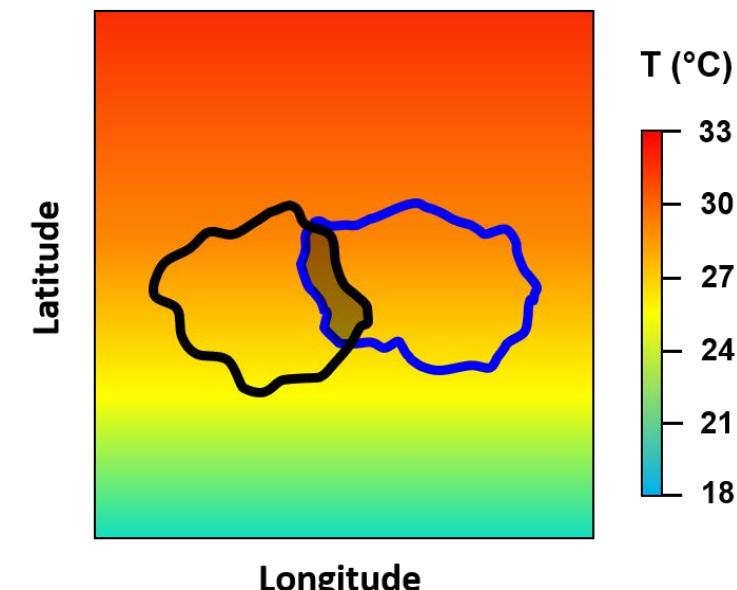
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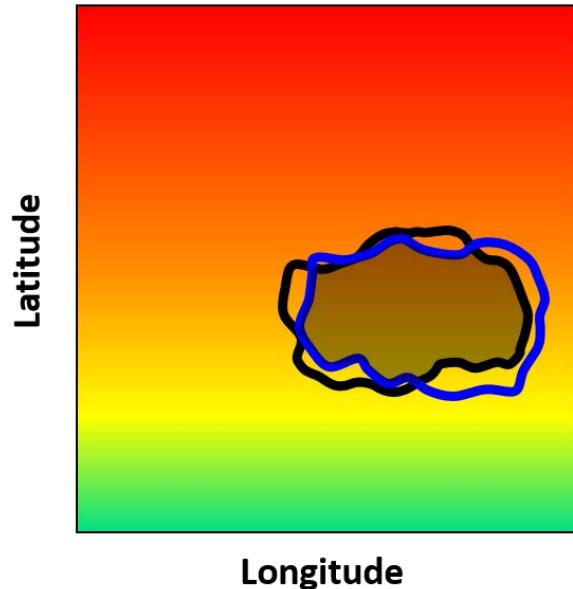
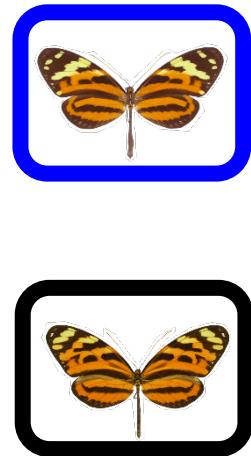


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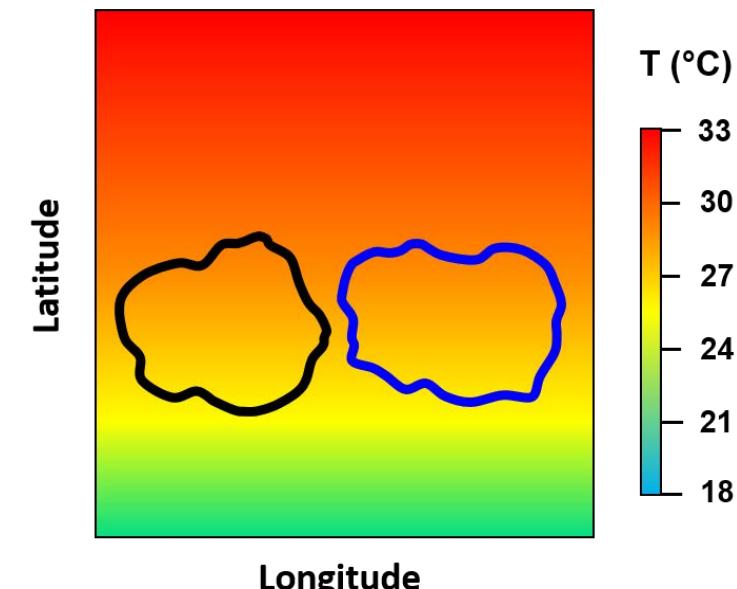
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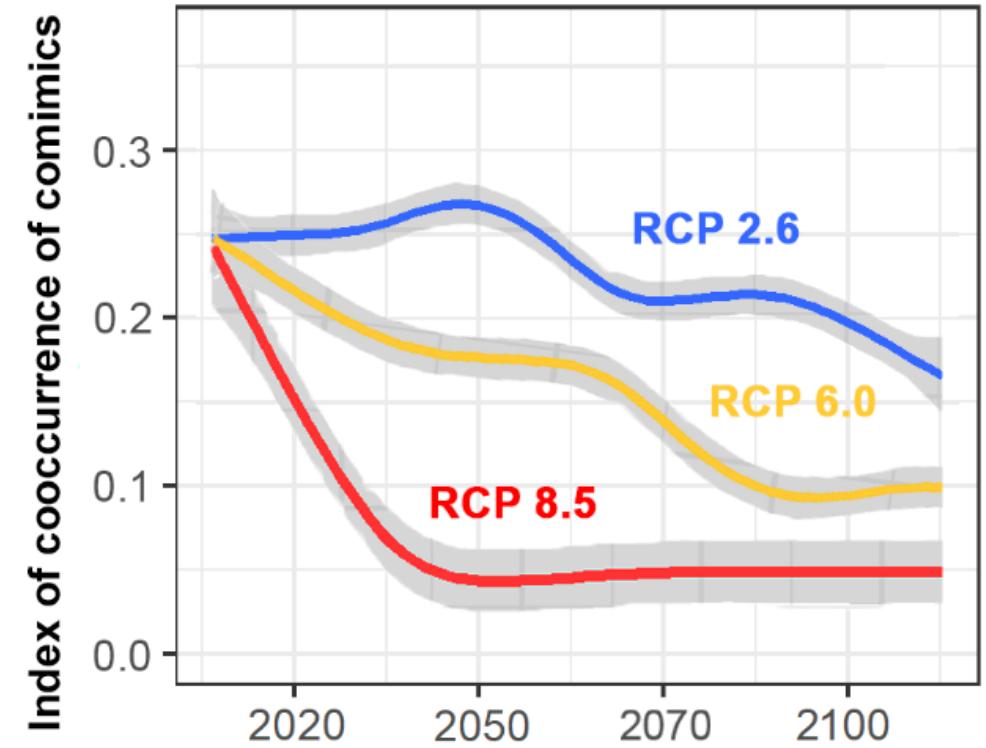
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Model **future distributions**:

- Representative Concentration Pathways (RCP)
- Shared Socioeconomic Pathways (SSP)



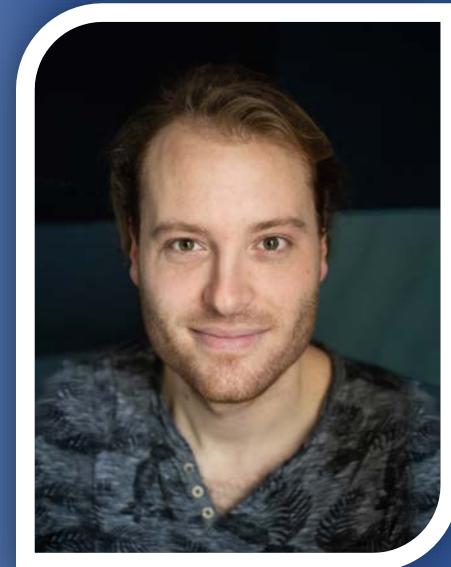
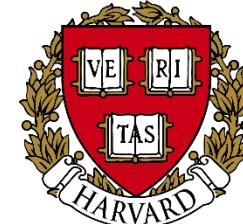
Research team

Advisors: Marianne Elias (ISYEB) & Colin Fontaine (CESCO)

Funding: PhD Grant (French MESR) & Marianne Elias (HFSP Grant)

Main collaborators:

- Keith Willmott, Florida University, USA
- Andre Freitas, Campinas State University, Brazil
- James Mallet, Harvard University, USA
- Nicolas Chazot, SUAS, Sweden



MaelDore



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