

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

Maël Doré

Marianne Elias, Colin Fontaine,  
Keith Willmott

Virtual Evolution – 2021



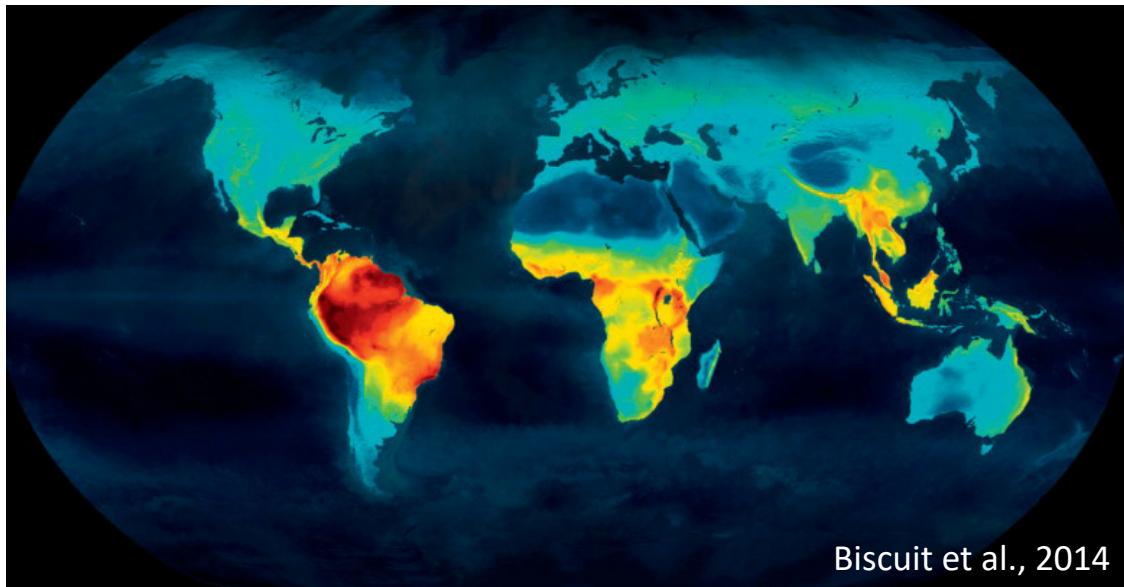
Credits: N. Chazot



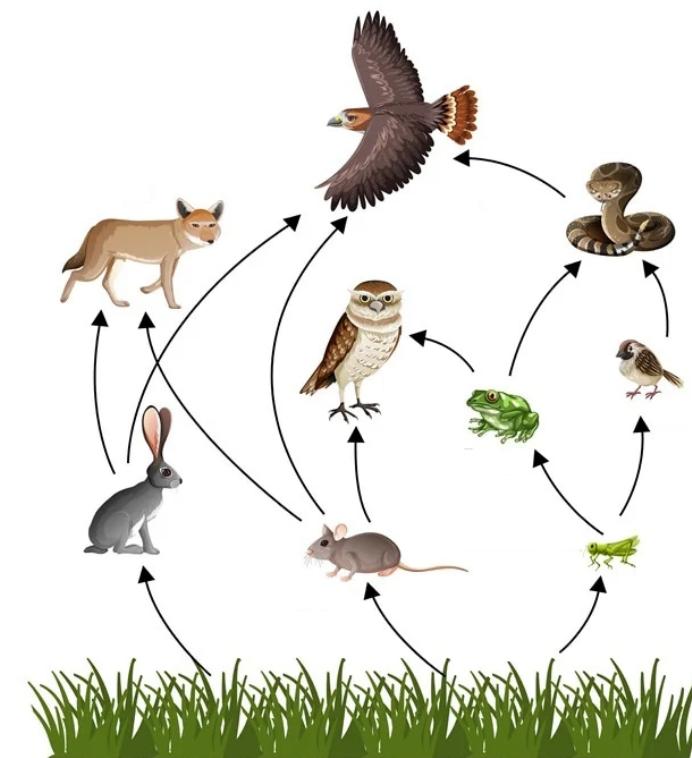
# Context

## Biodiversity

### Biological units



### Interactions



Credit: Shutterstock.com

# Context

## Biodiversity

### Interactions

Negative



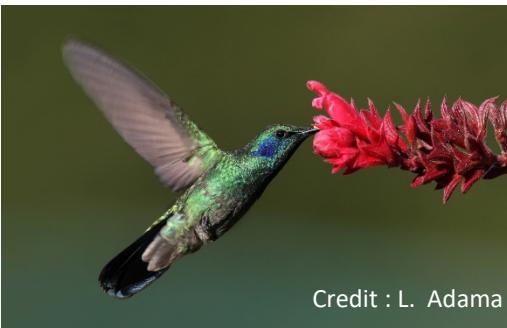
Inter-guild



Intra-guild



Positive



Adapted from Mallet, 2014

# Context

## Biodiversity

### Interactions

	Inter-guild	Intra-guild
Negative	<p>Web of Science </p> <p><b>Results: 6,170</b> (from Web of Science Core Collection)</p> <p>You searched for: TOPIC: (community structure <b>predation</b>) <a href="#">...More</a></p>	<p>Web of Science </p> <p><b>Results: 9,246</b> (from Web of Science Core Collection)</p> <p>You searched for: TOPIC: (community structure <b>competition</b>) <a href="#">...More</a></p>
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## Biodiversity

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# Context

## Mutualistic interactions:

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



Credits: Amanda R. Liczner



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Credits: safari-consultants.com



Credits: Jason L. Brown

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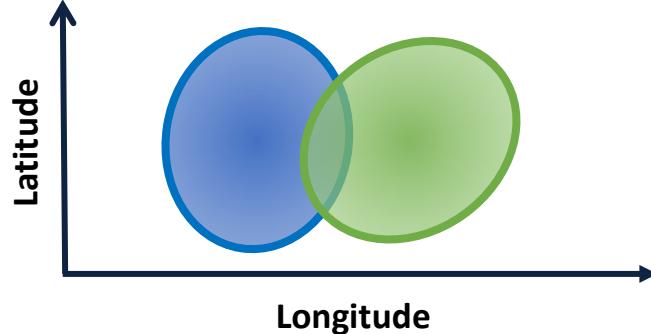
## Exploitative competition:

- for local resources
- for habitats
- for space



# Context

## Spatial distribution



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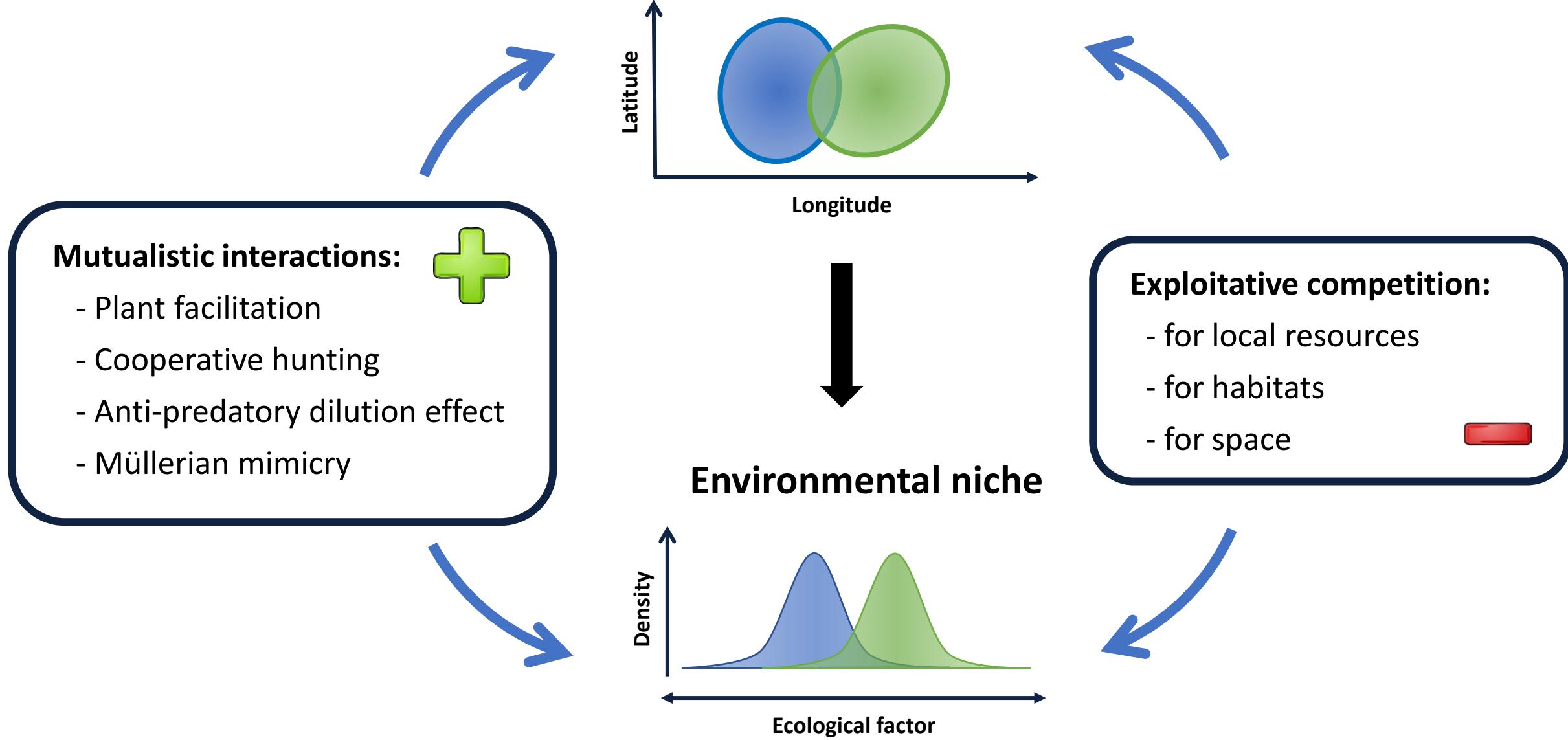


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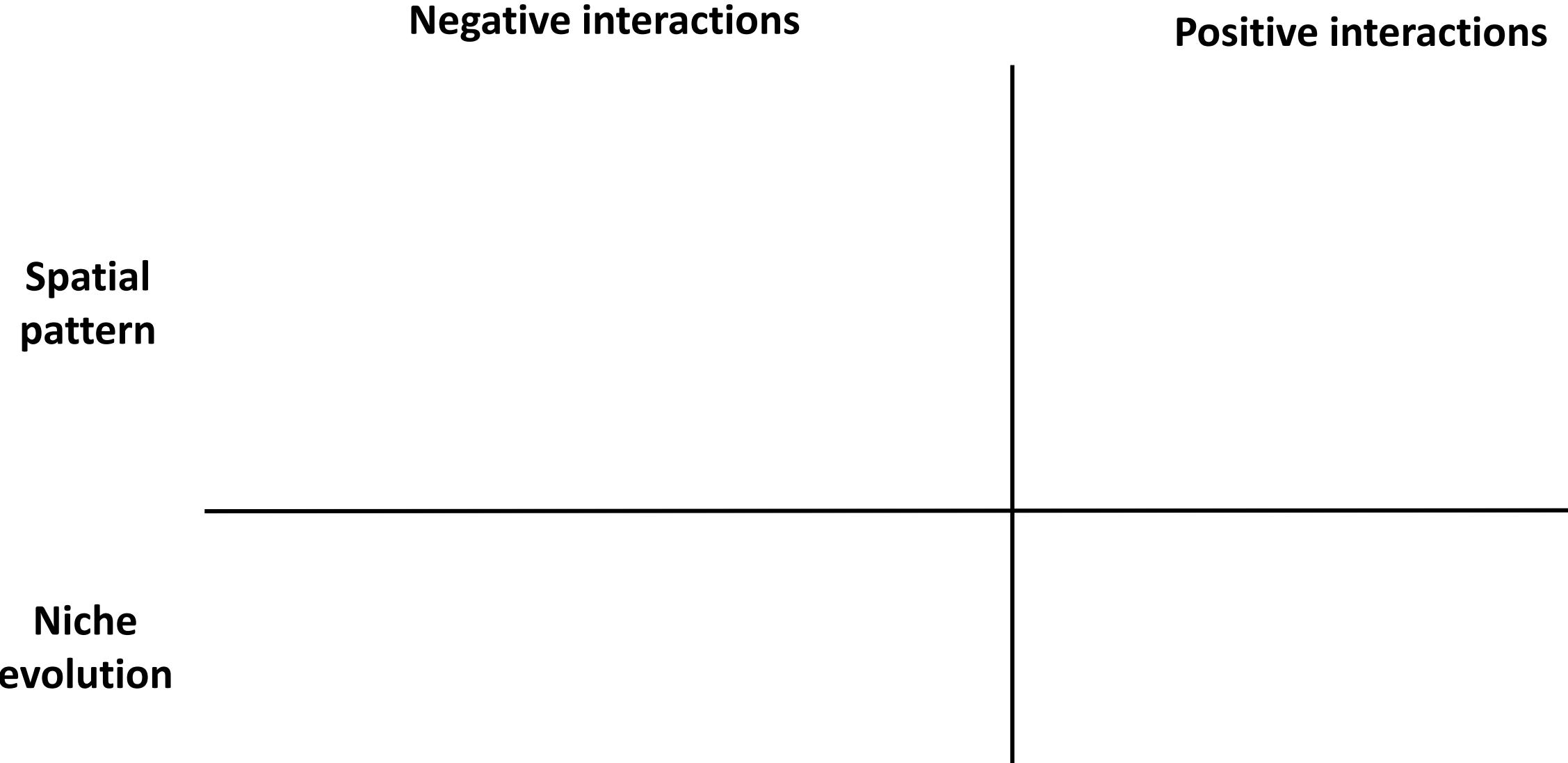
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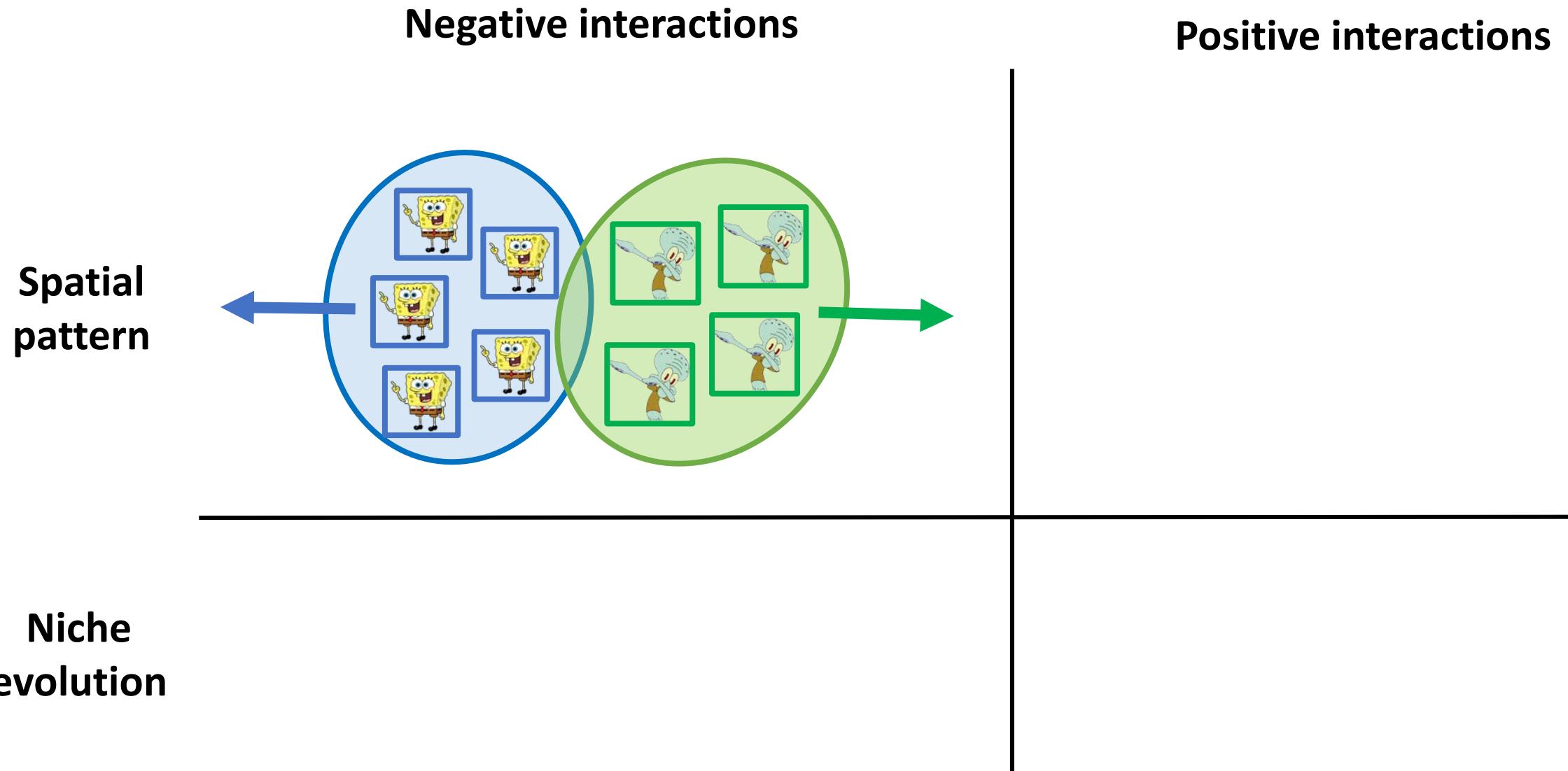
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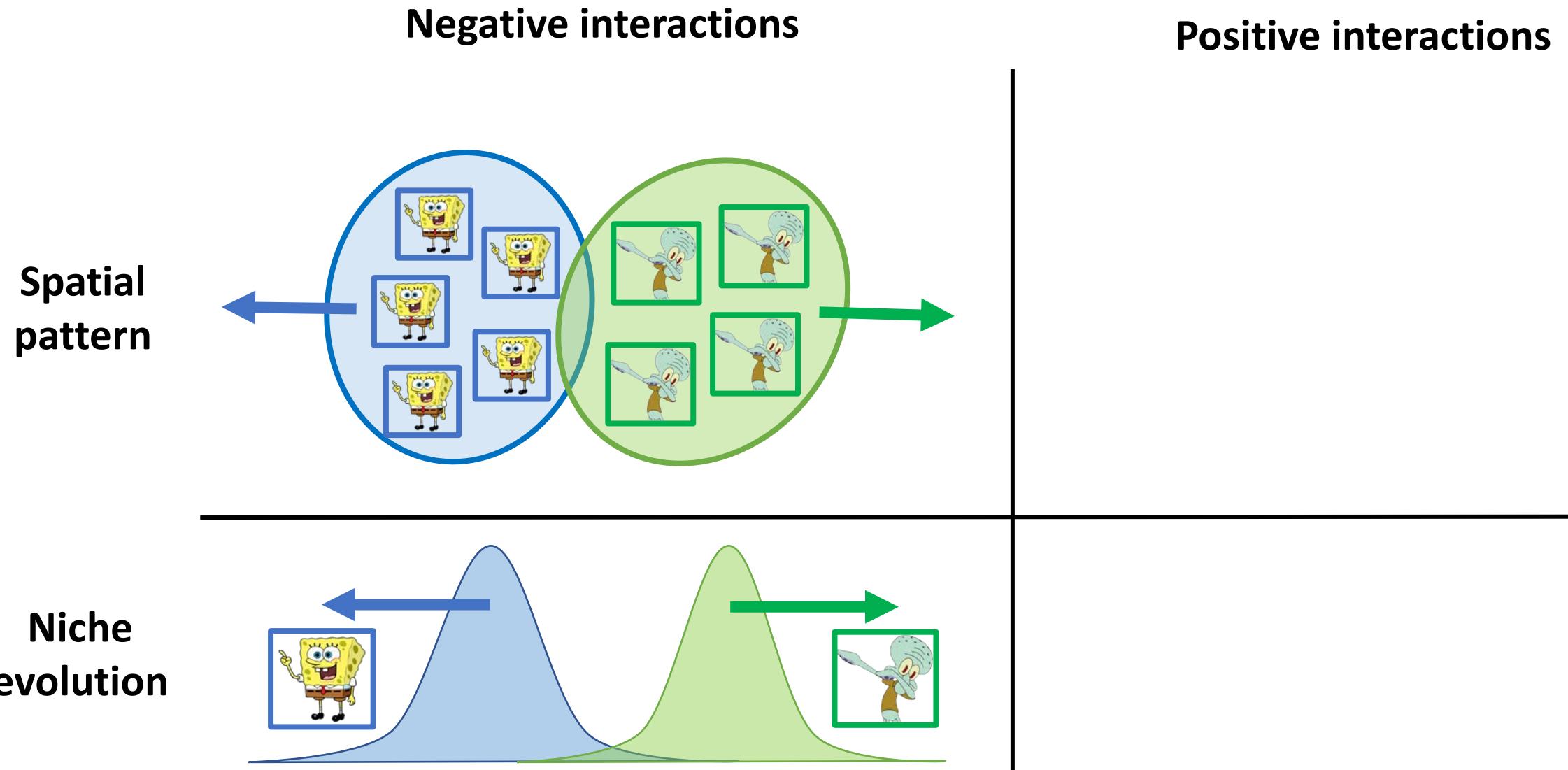
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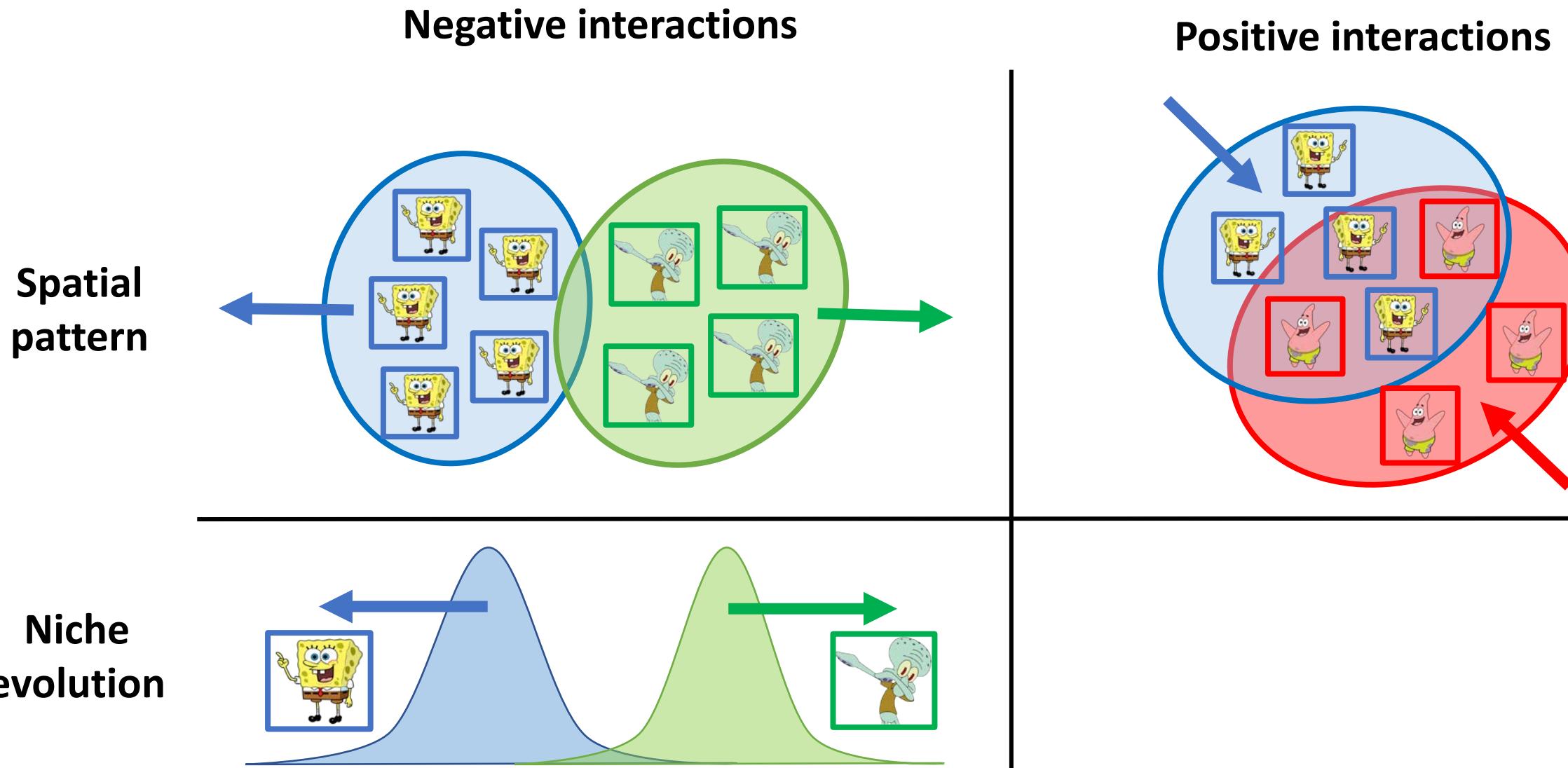
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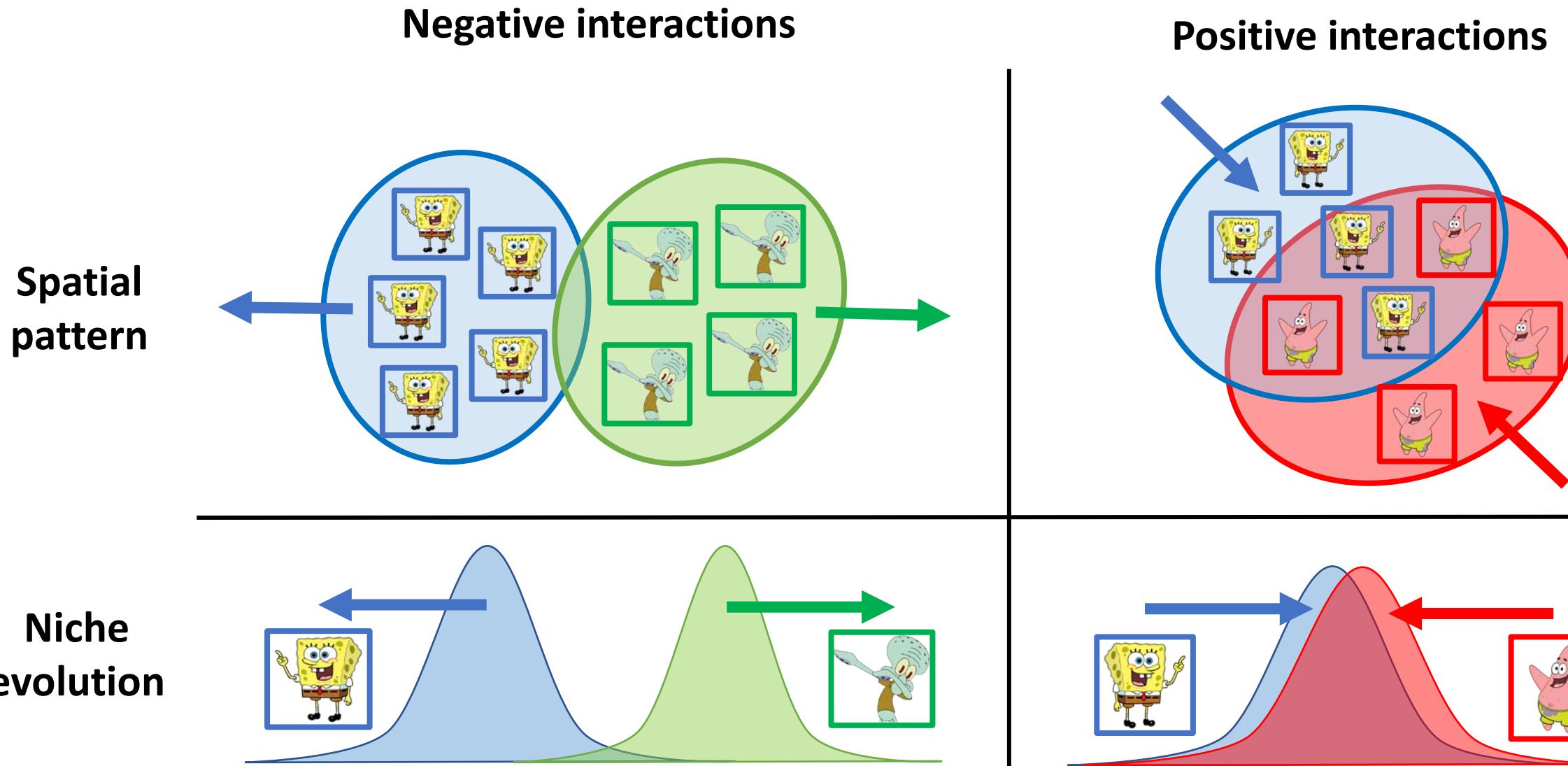
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# Questions & Hypotheses

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

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

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

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**Niche evolution**

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# Study system: Müllerian mimicry

Aposematism: warning signals

Shared signals = mutualistic interactions

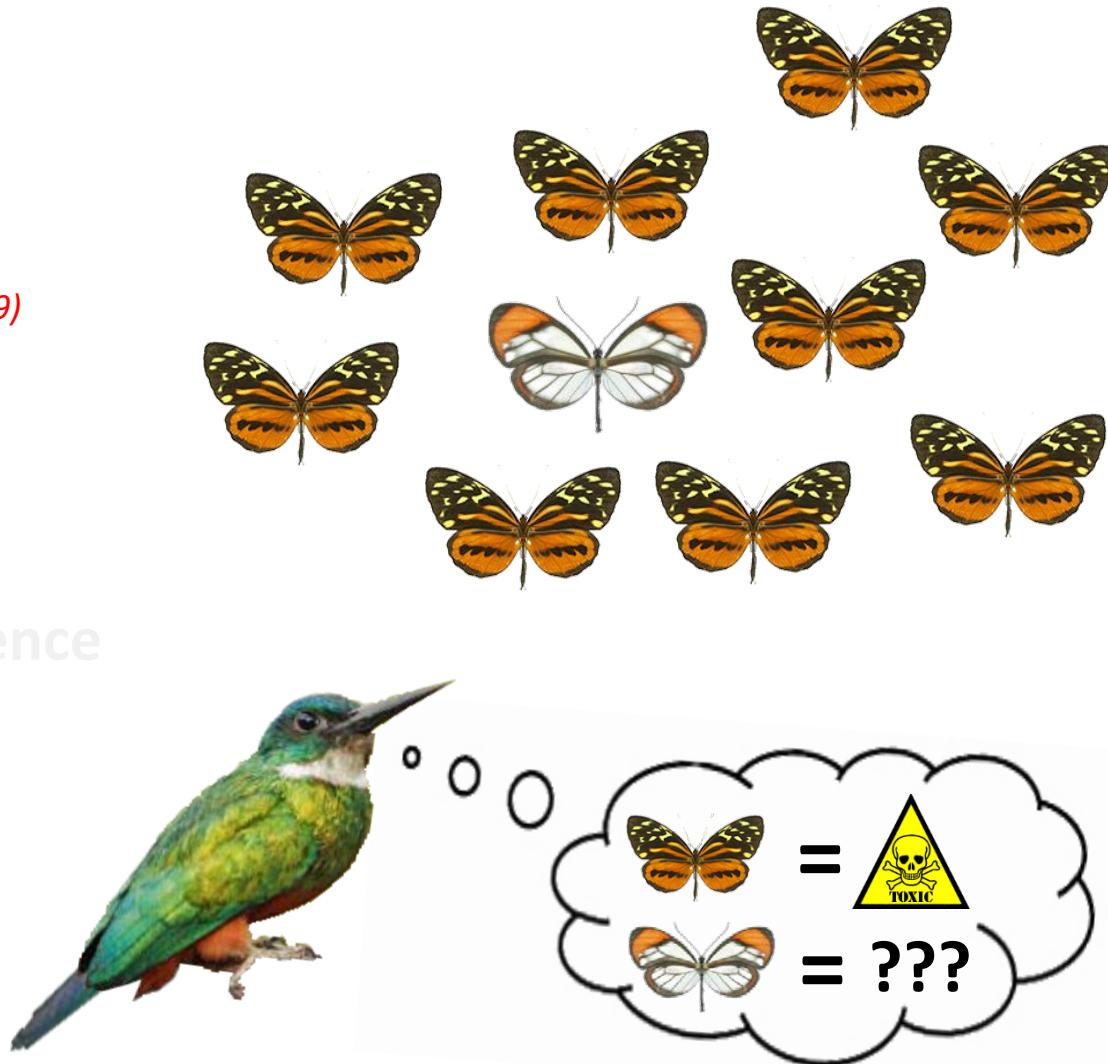
Positive frequency-dependent selection *(Müller, 1879)*

Consequences:

- Convergence of local patterns *(Sherratt, 2008)*
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Macroecological scale?

- Community composition
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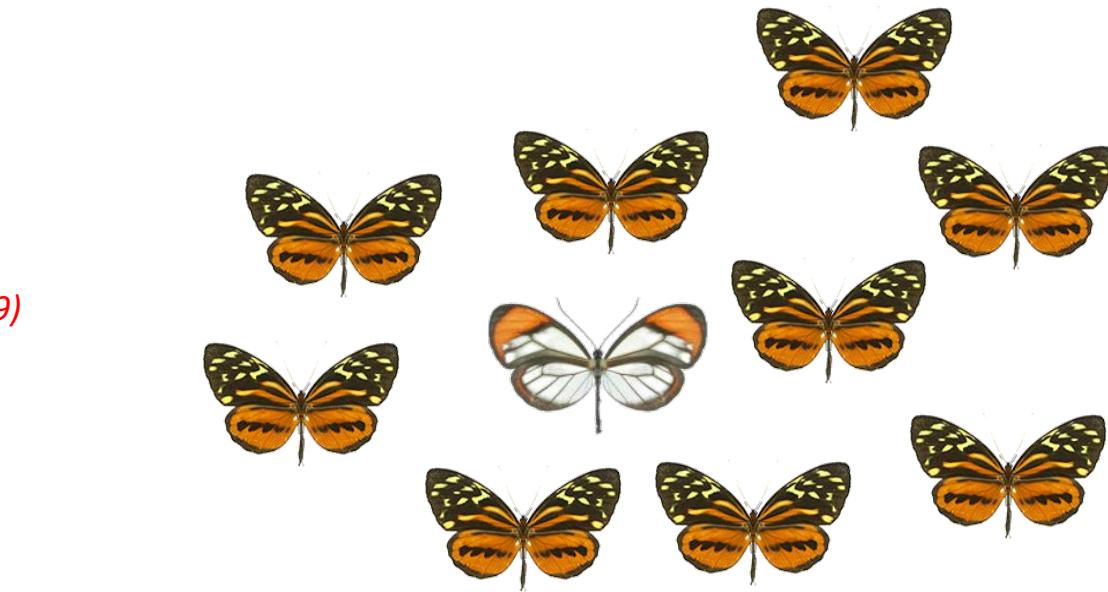
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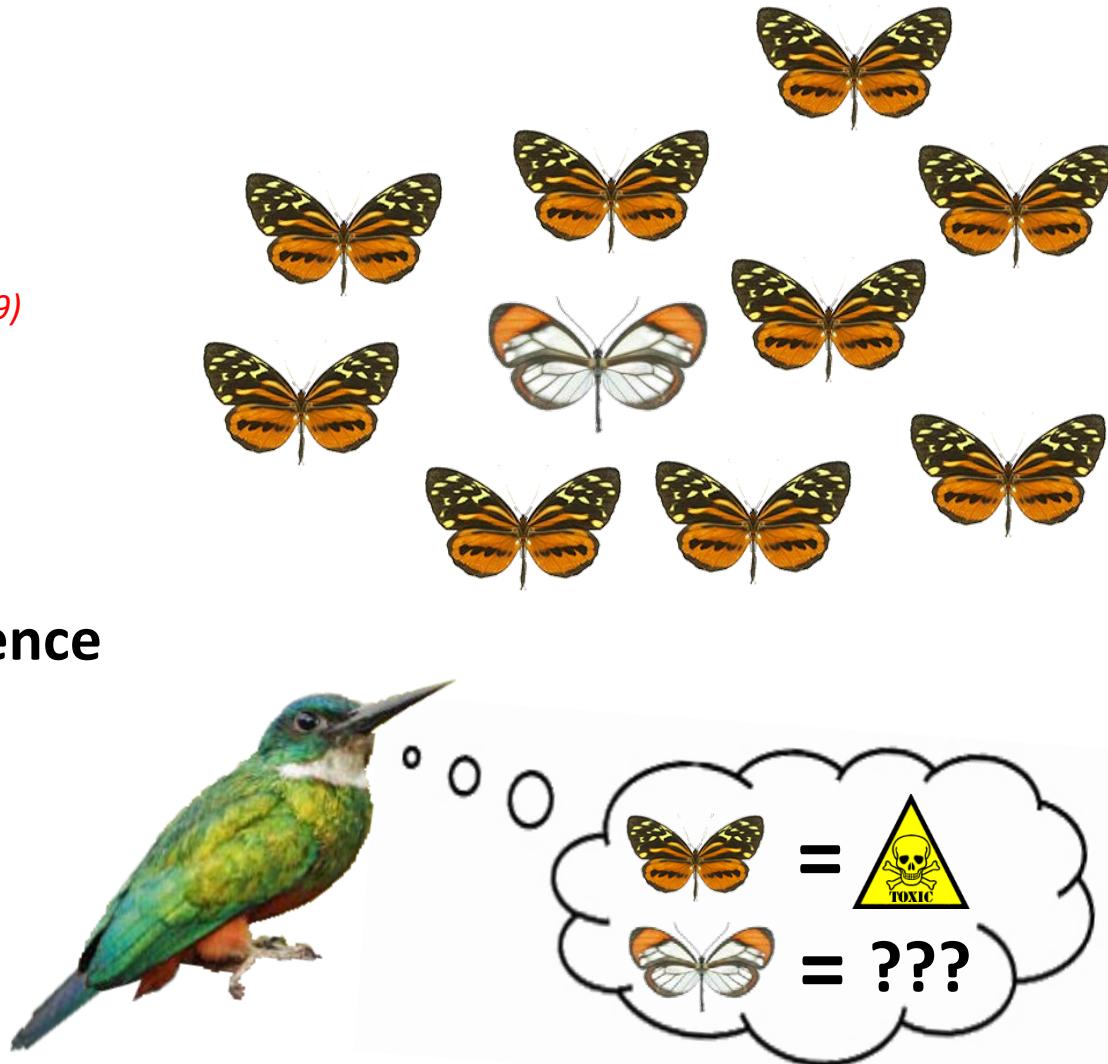
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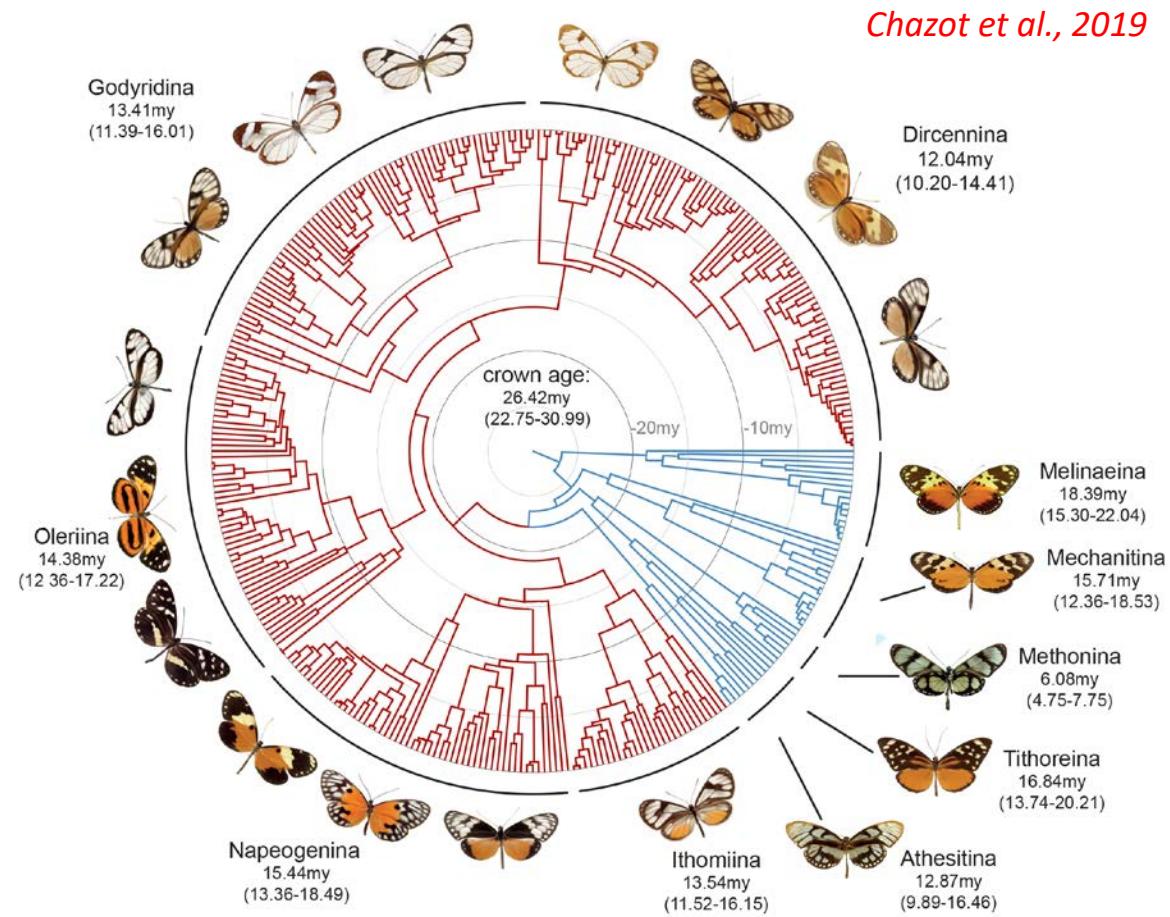
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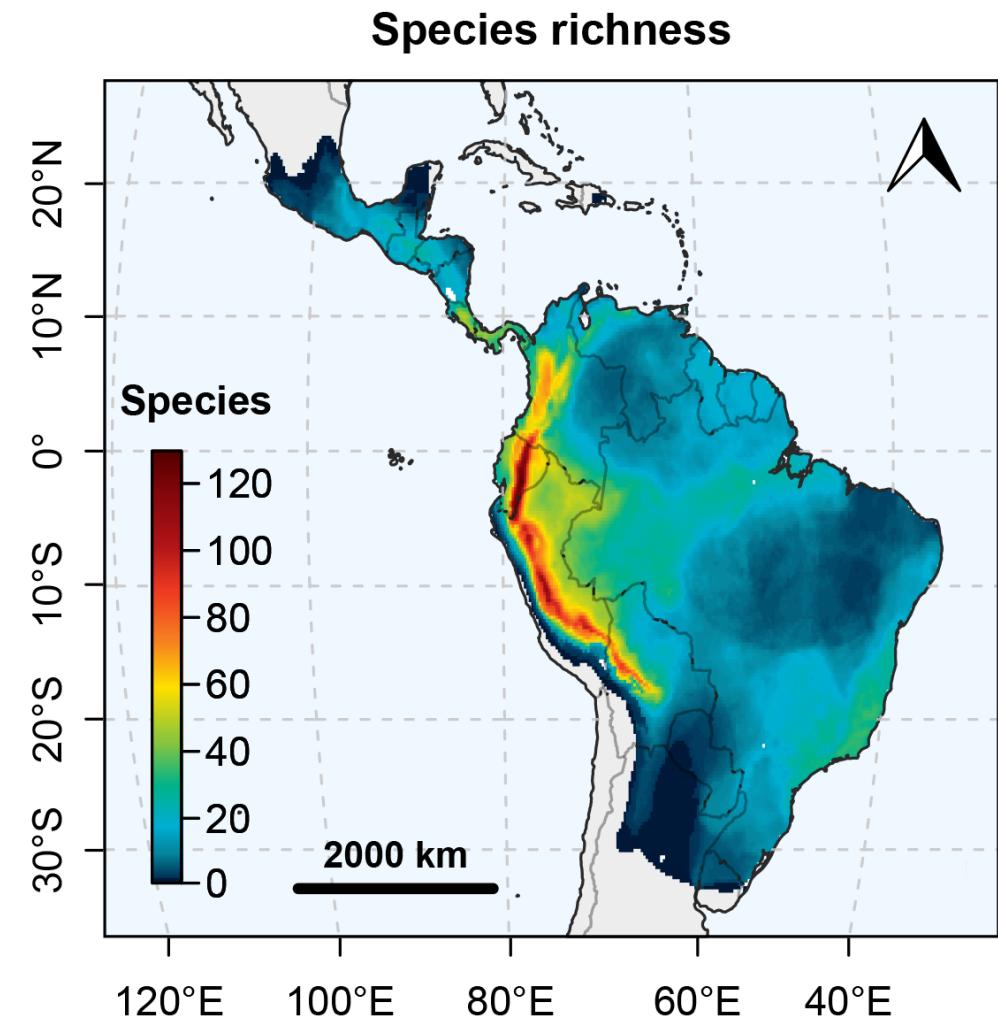
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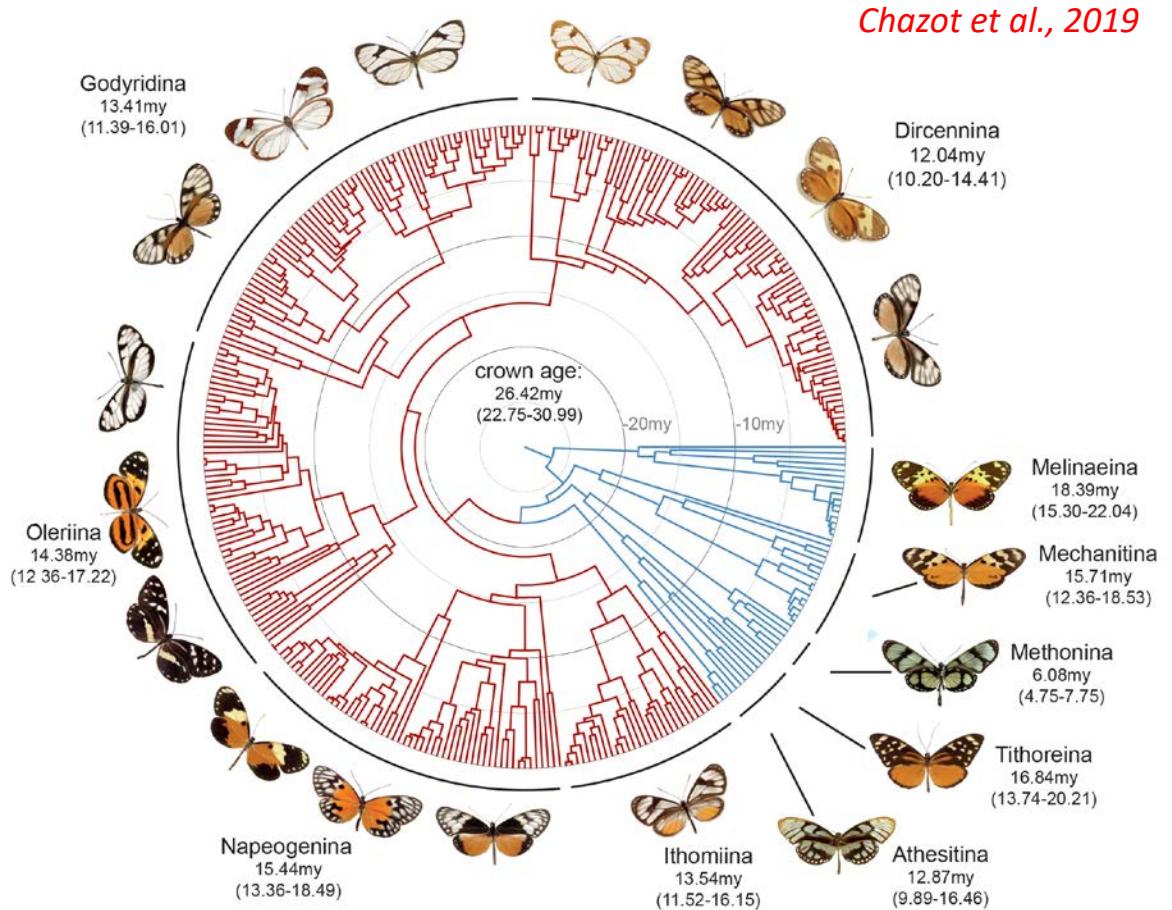
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Adaptative radiation: 393 species in 25 My



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Chazot et al., 2019



Credits: Nicolas Chazot

Adaptative radiation: 393 species in 25 My

44 mimicry rings (*sensu* K. Willmott)

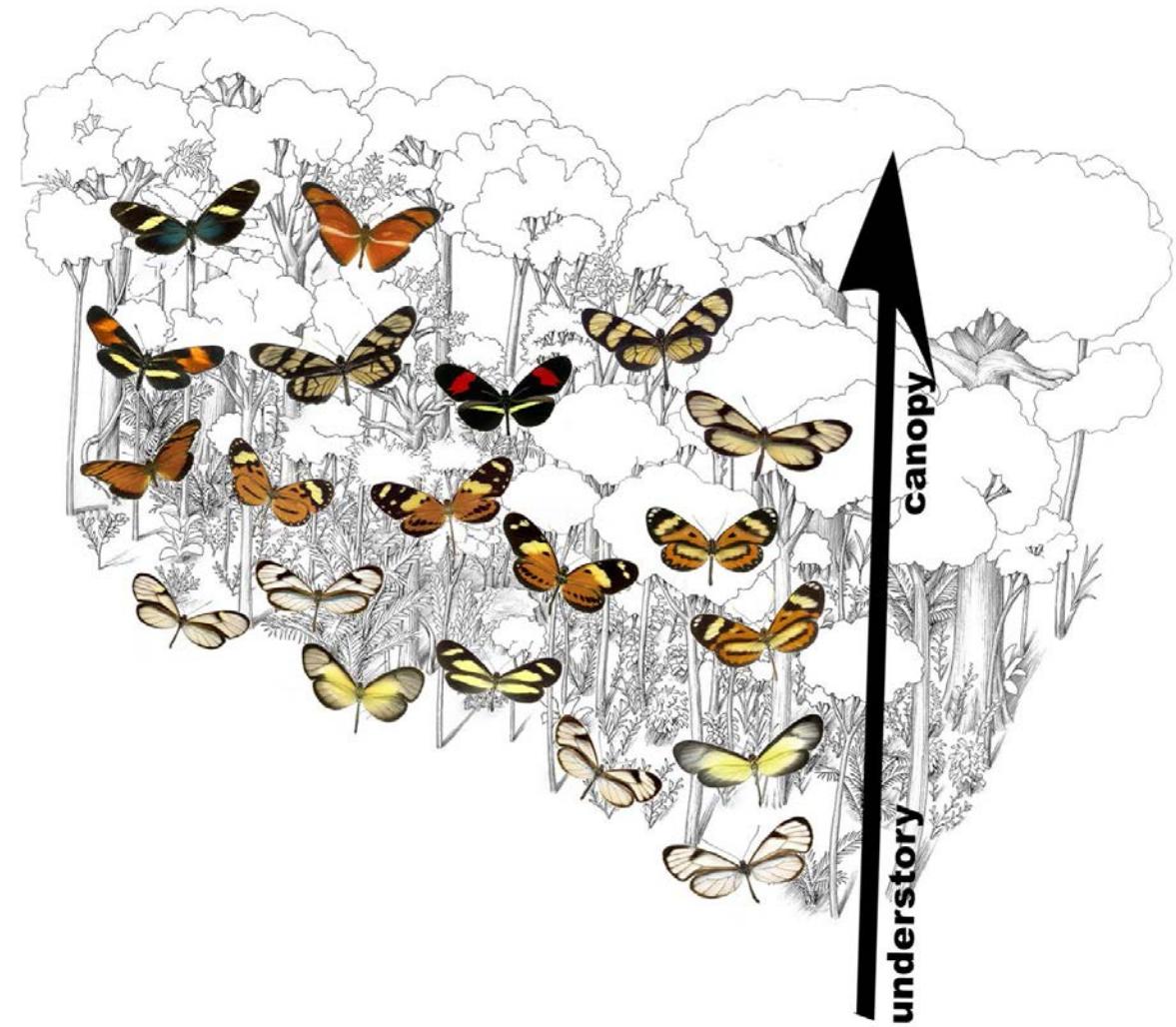
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Limits :

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



Adapted from Birskis-Baros et al., 2021

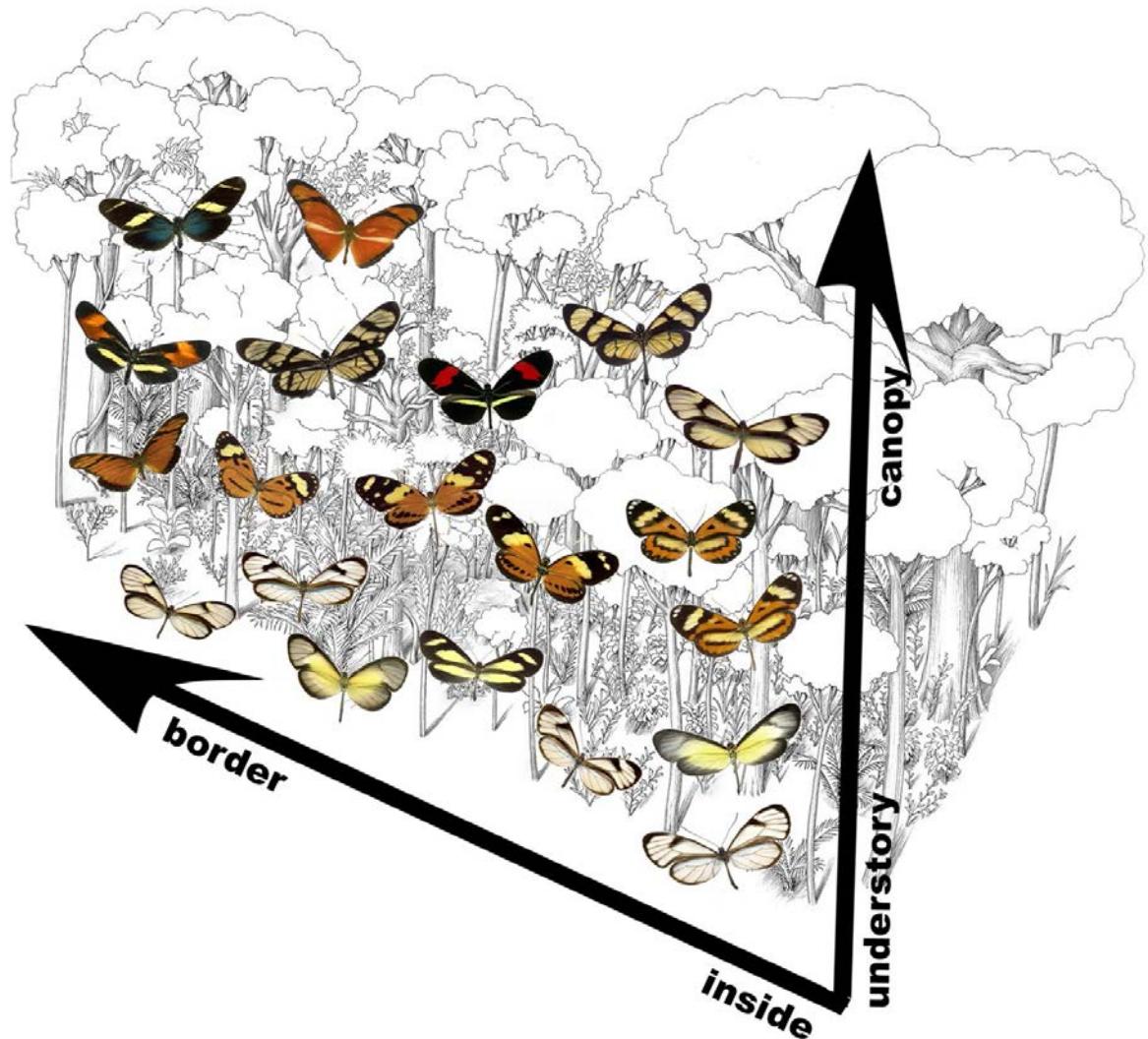
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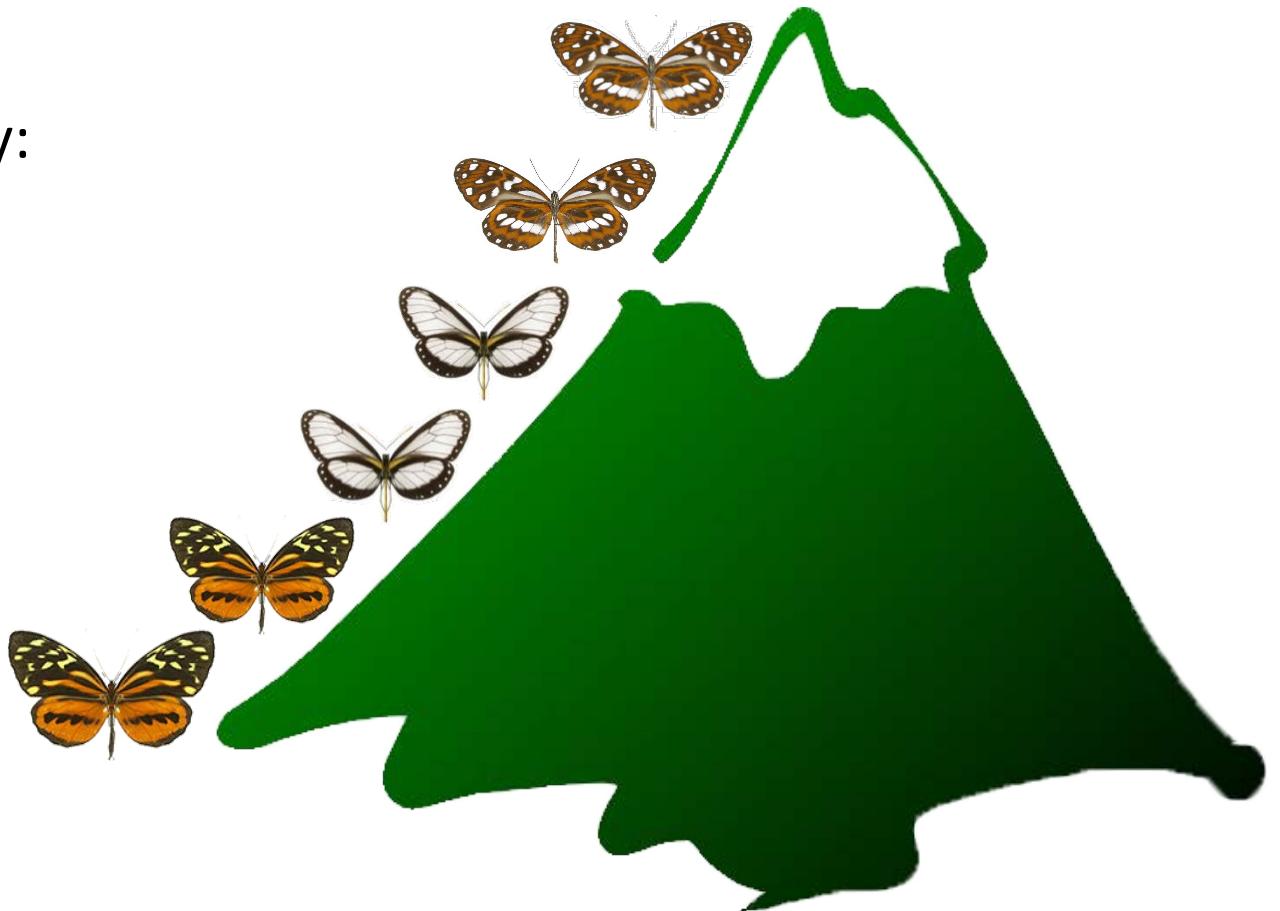
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Dimensions = climatic niche

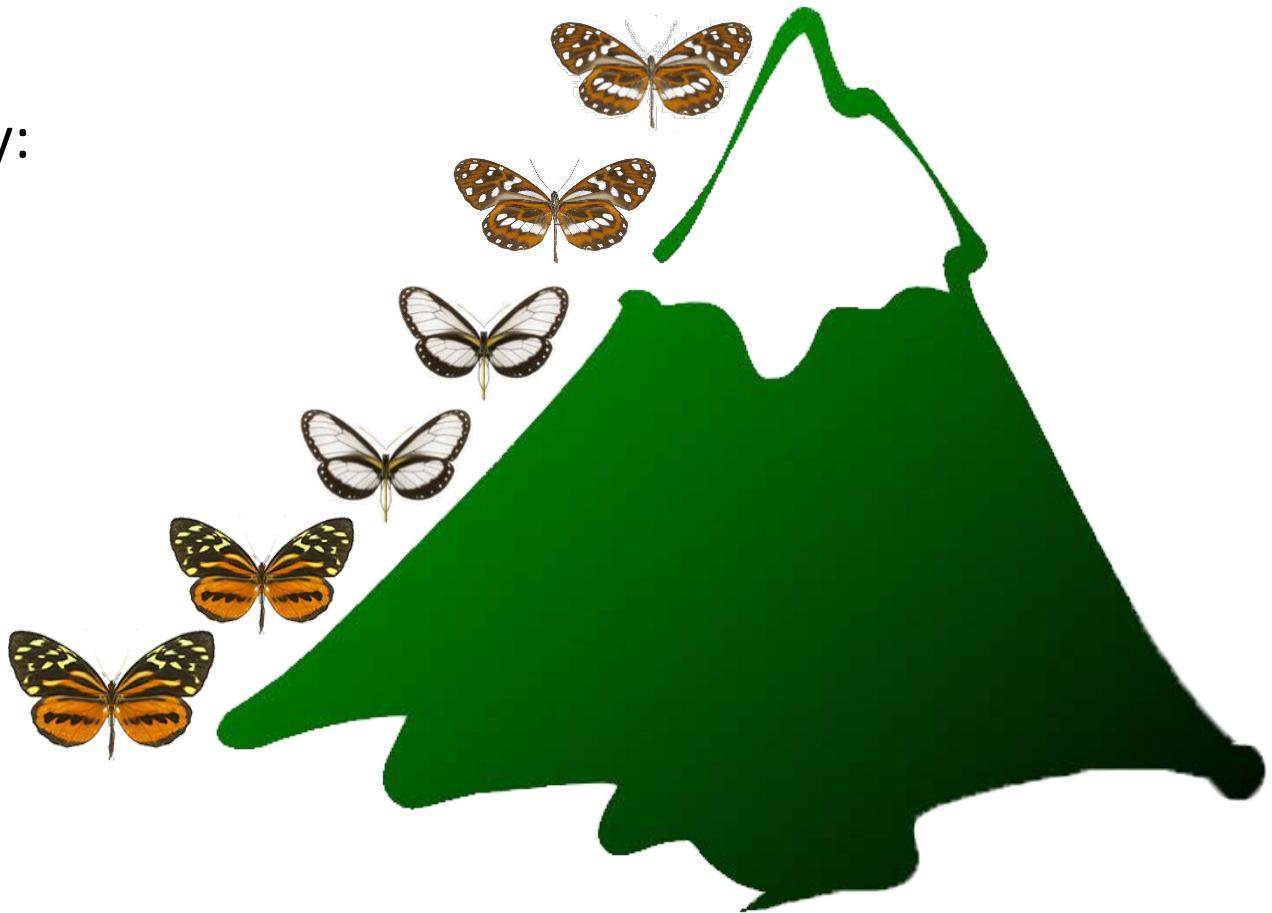
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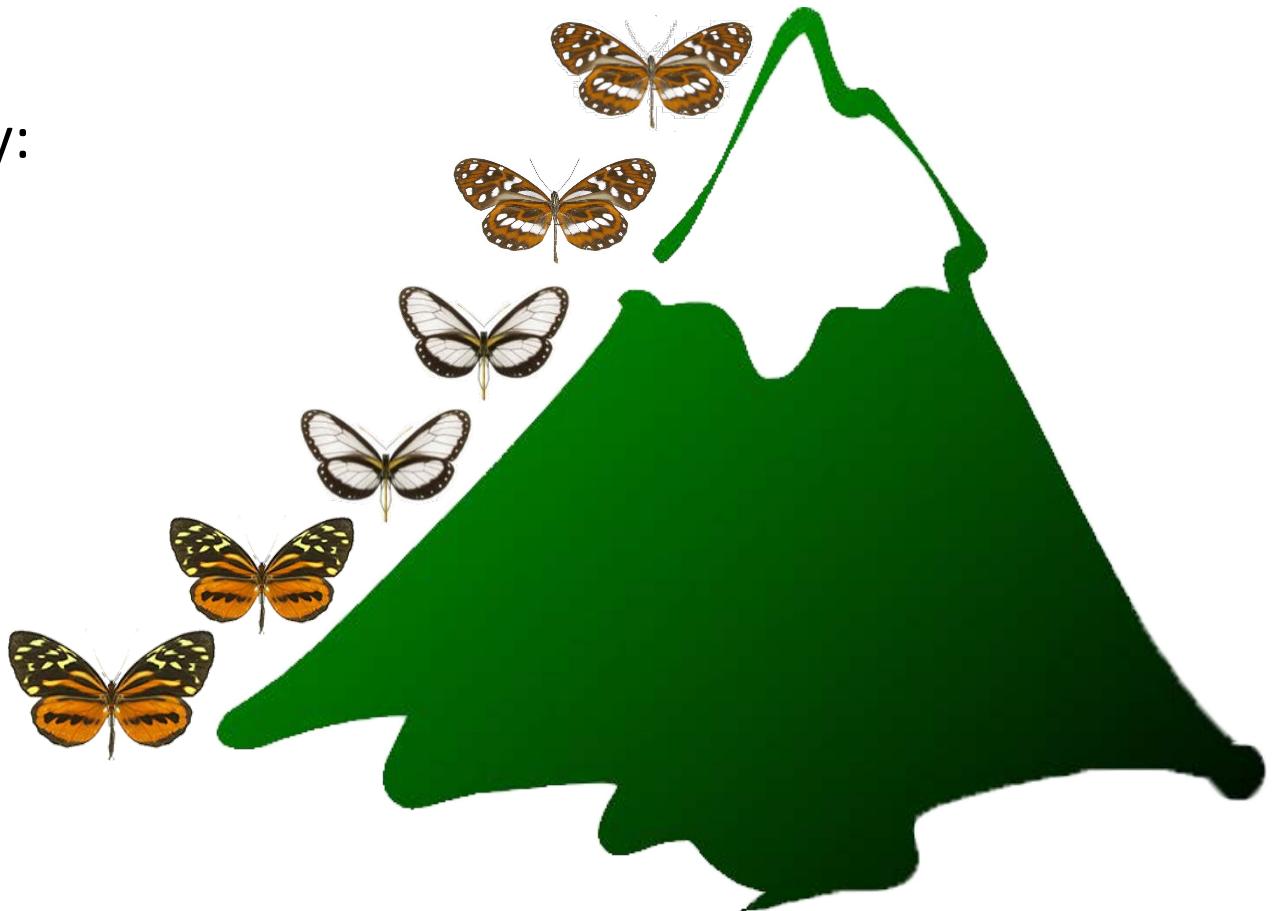
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# Objectives

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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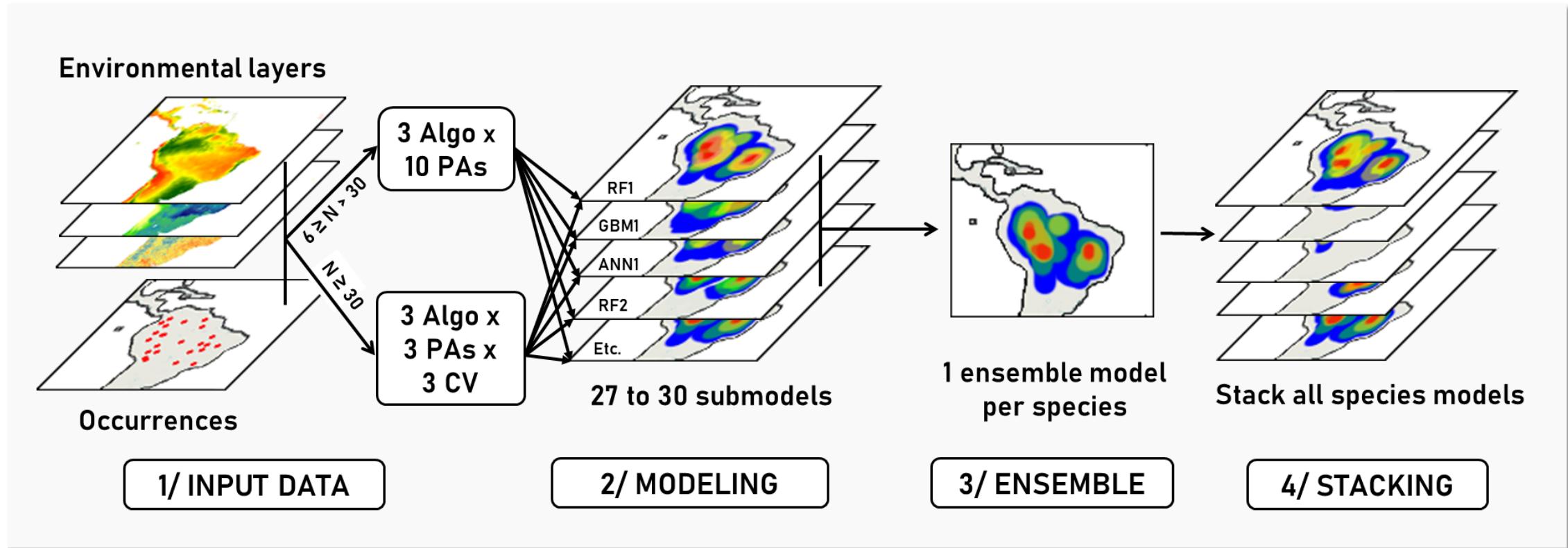
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# Species Distribution Models



SDM → Species distribution maps → Community composition

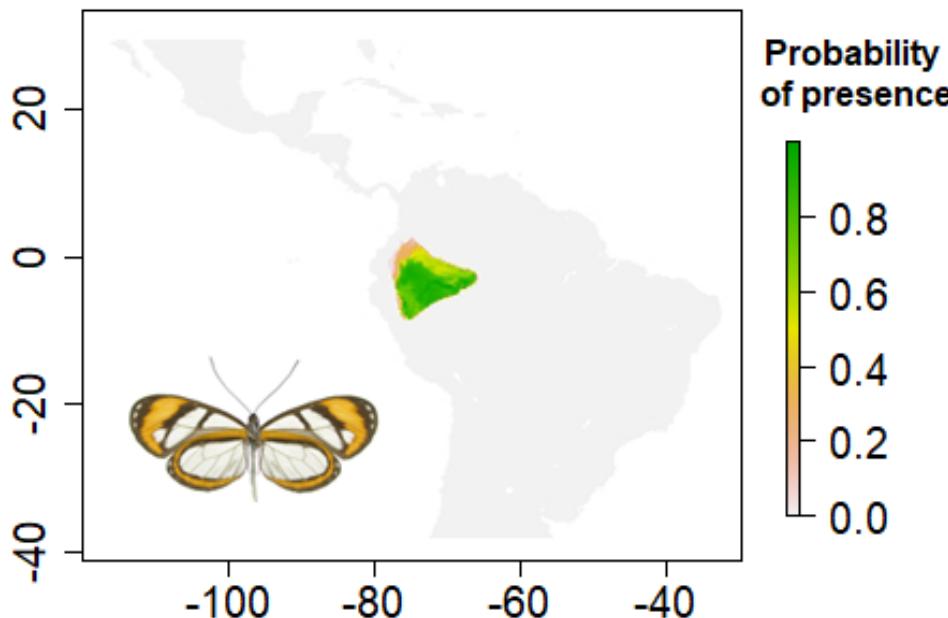
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**Question:** Do comimetic species **cooccur** more than expected at **random**?

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

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

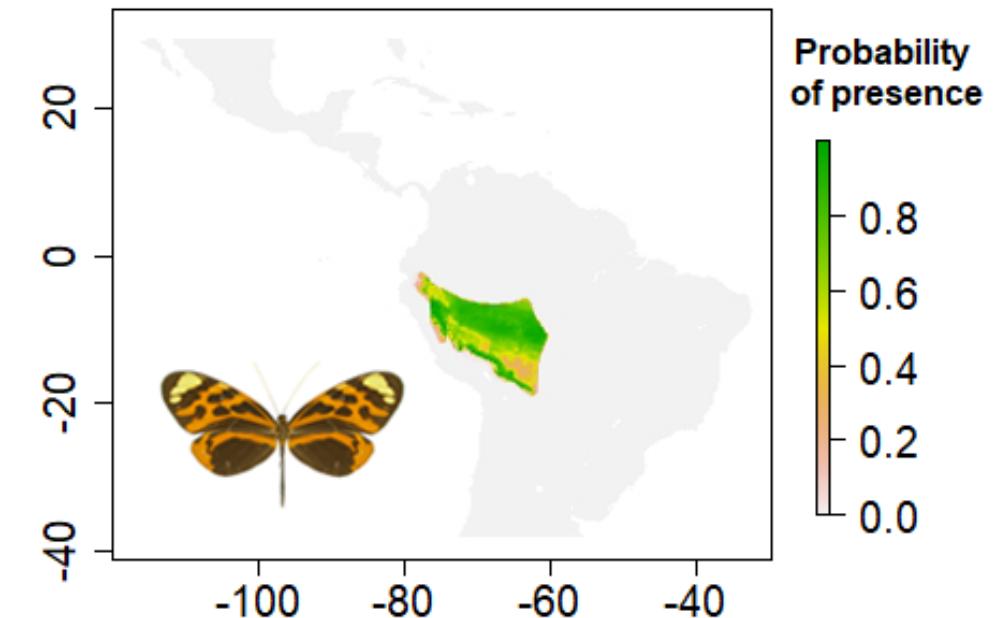
*Hypoleria aureliana* (AURELIANA)



No mimicry

BC = 0.9

*Hypothisis cantabrica* (MAMERCUS)



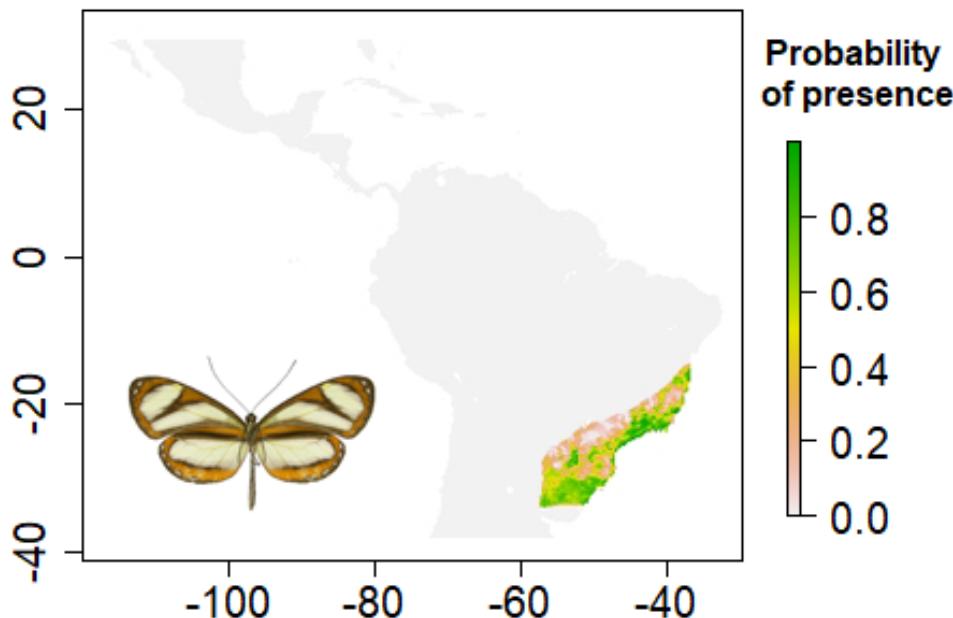
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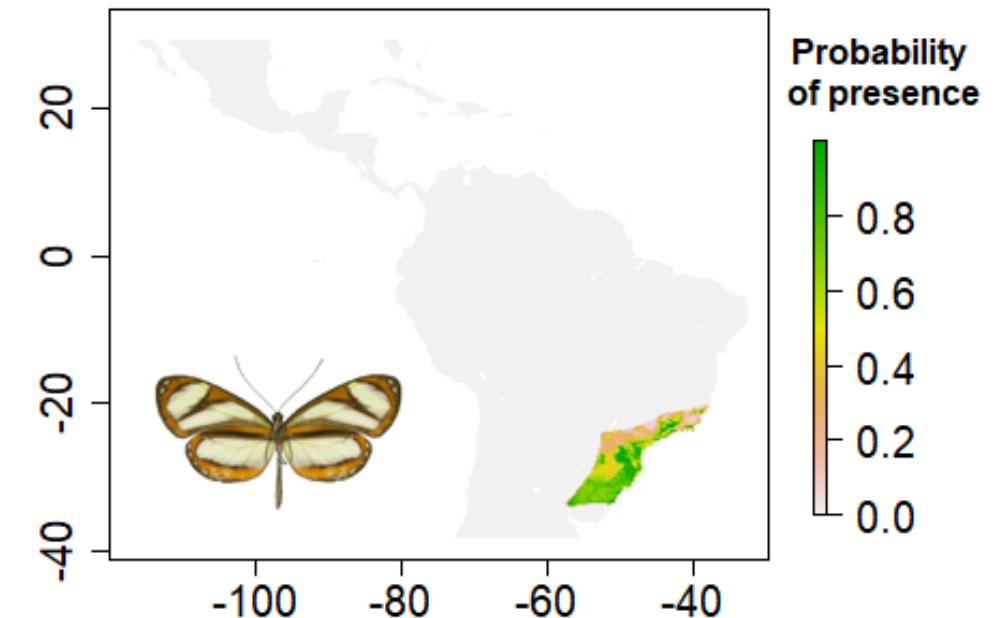
*Epityches eupompe* (EURIMEDIA)



Mimicry

BC = 0.2

*Episcada philoclea* (EURIMEDIA)



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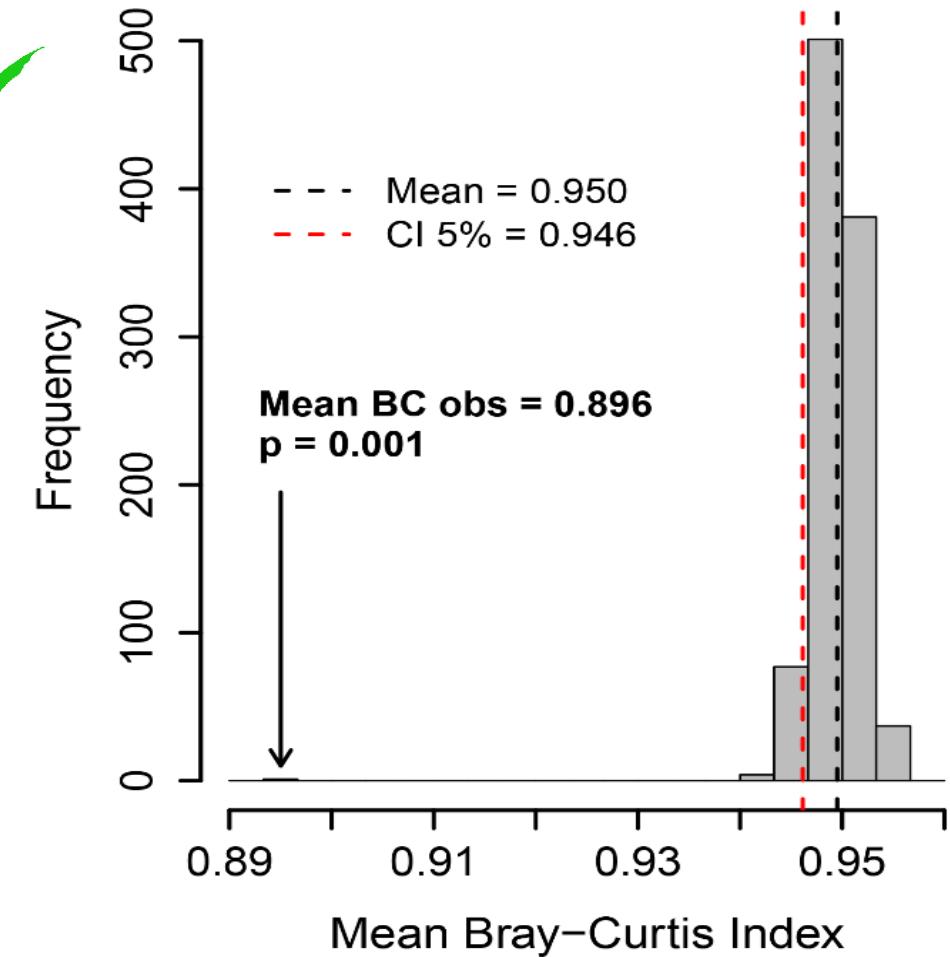
**Global:** Mean  $BC_{obs}$  << Mean  $BC_{perm}$  ;  $p = 0.001$



**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?



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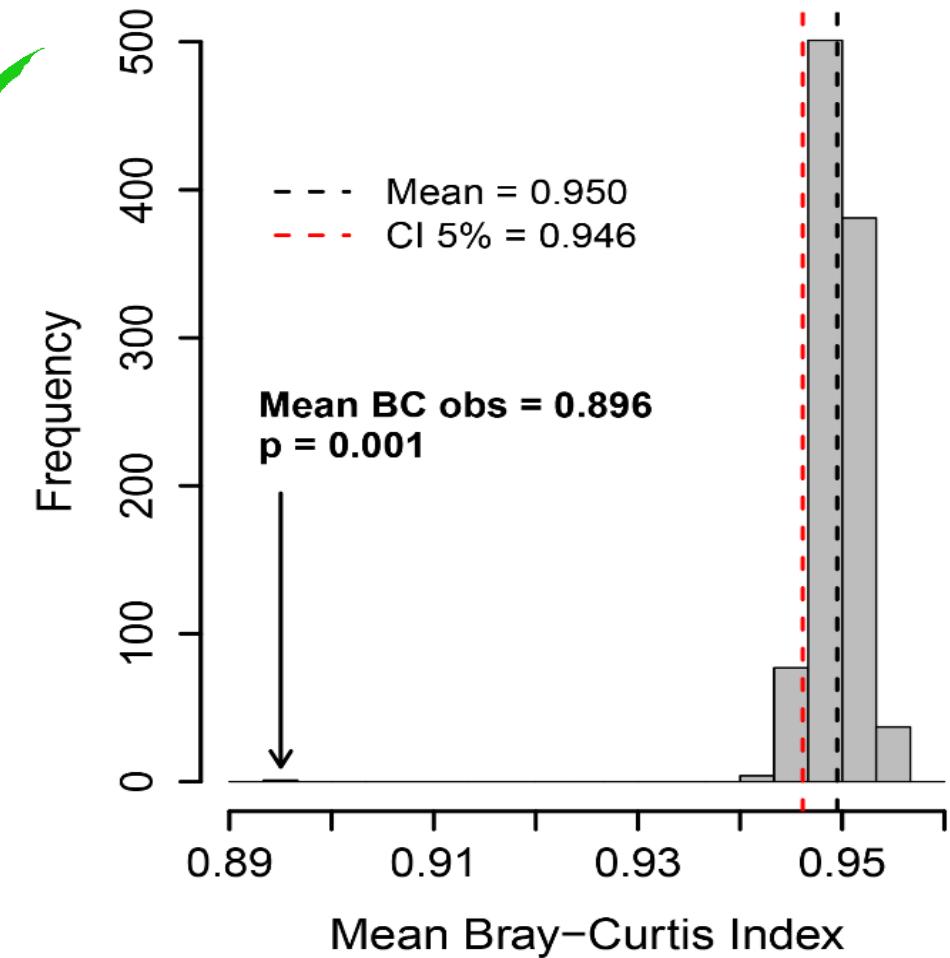
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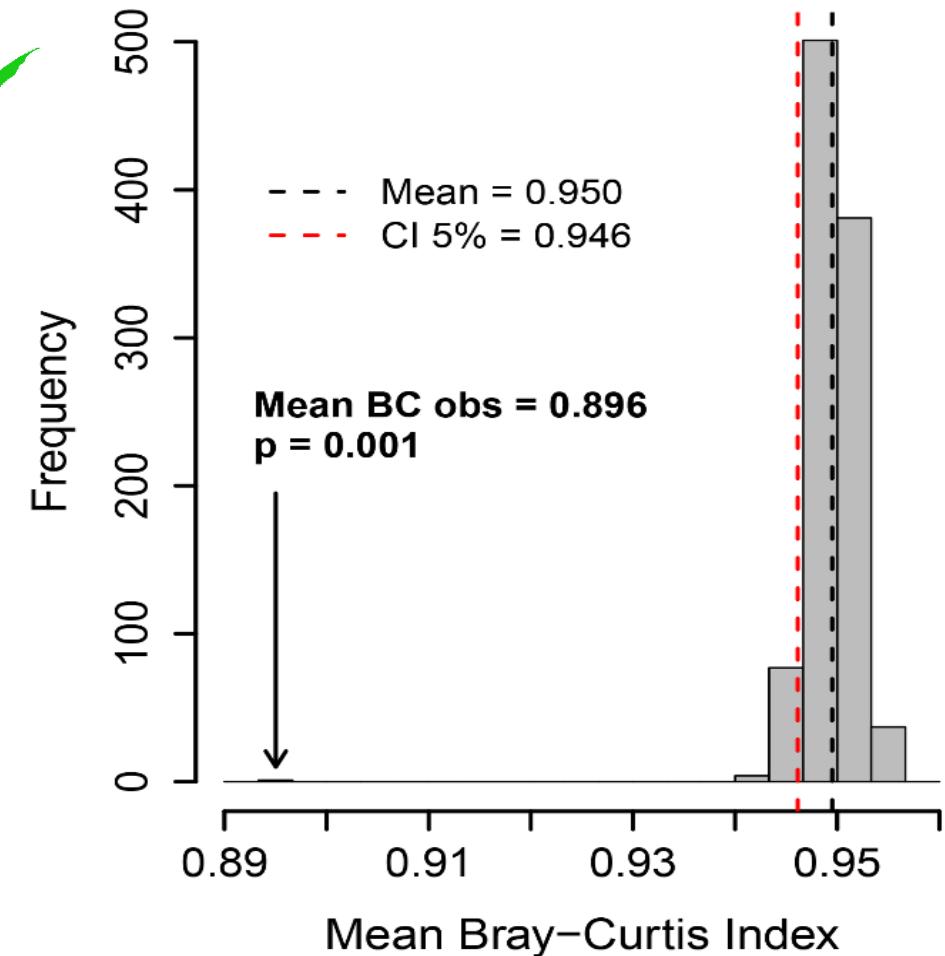
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Question: Do mimicry rings occupy different climatic niche?

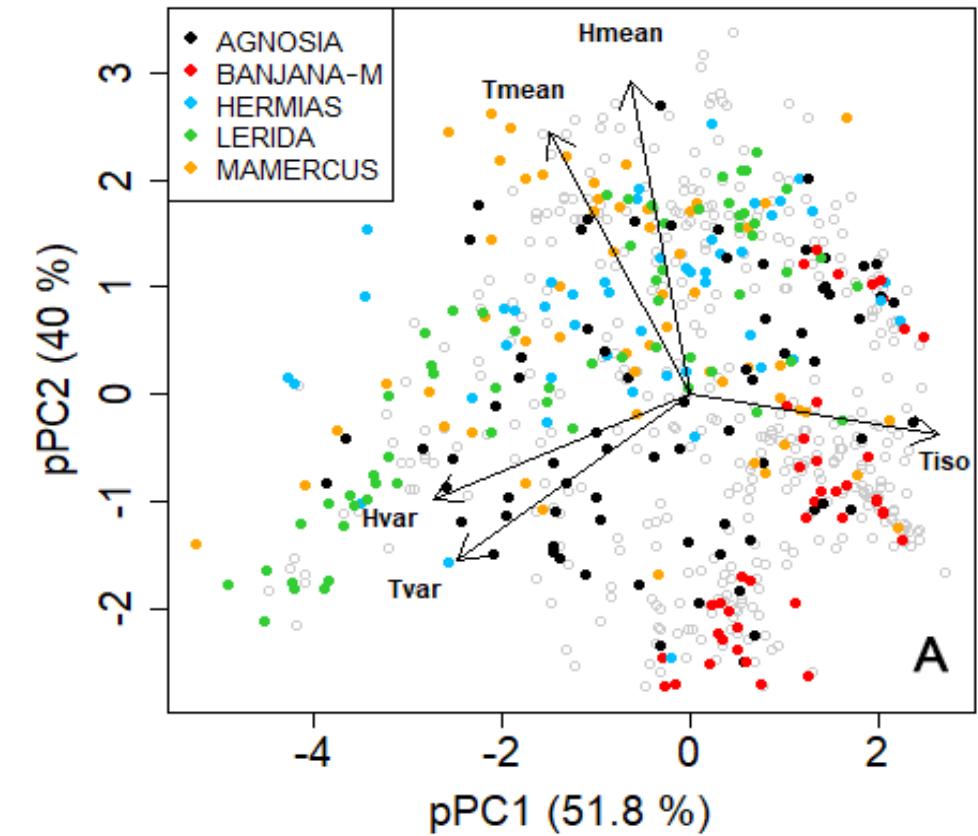
Global: perMANOVA,  $R^2 = 0.41$ ,  $p = 0.001$



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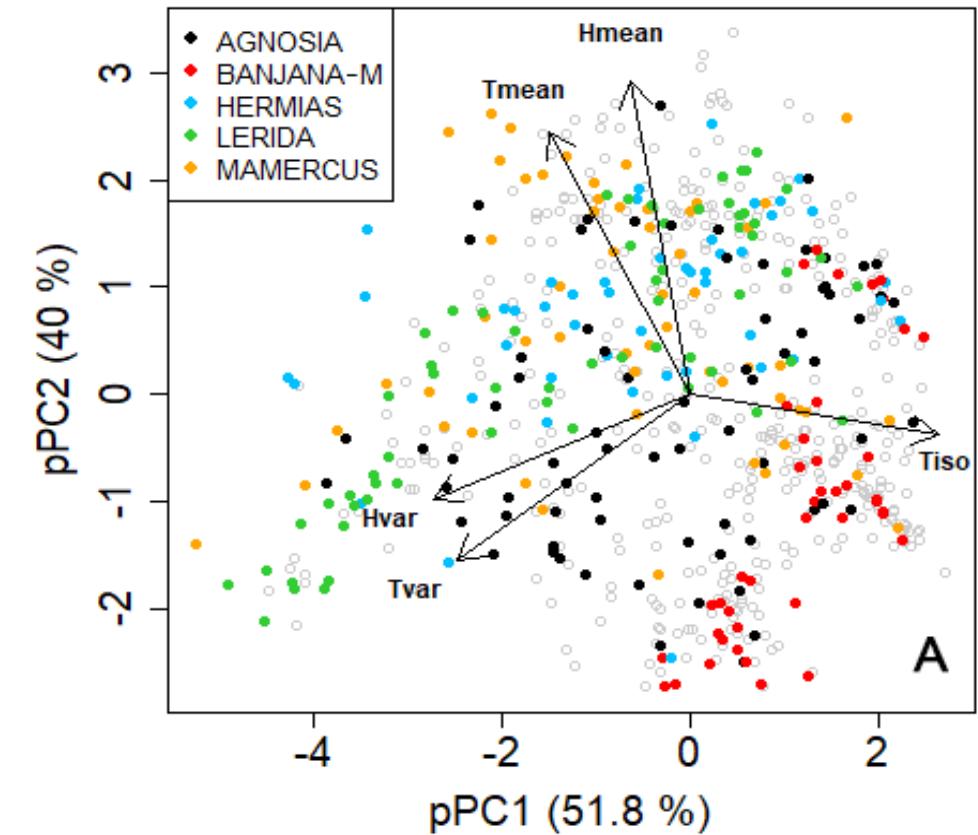
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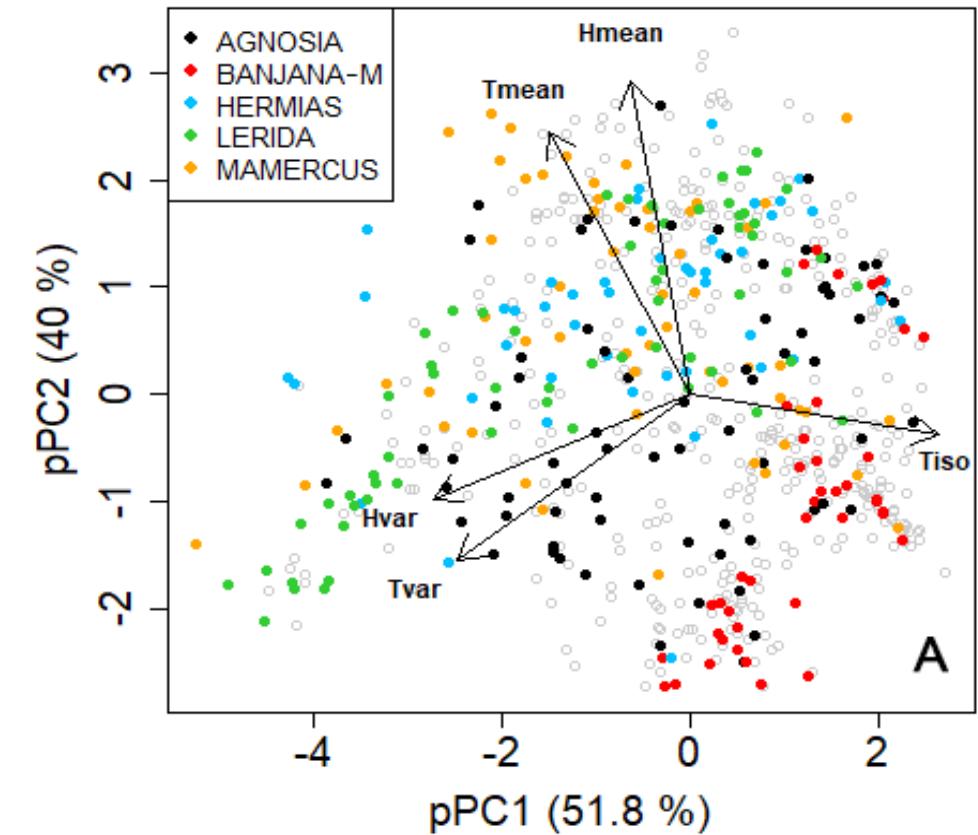
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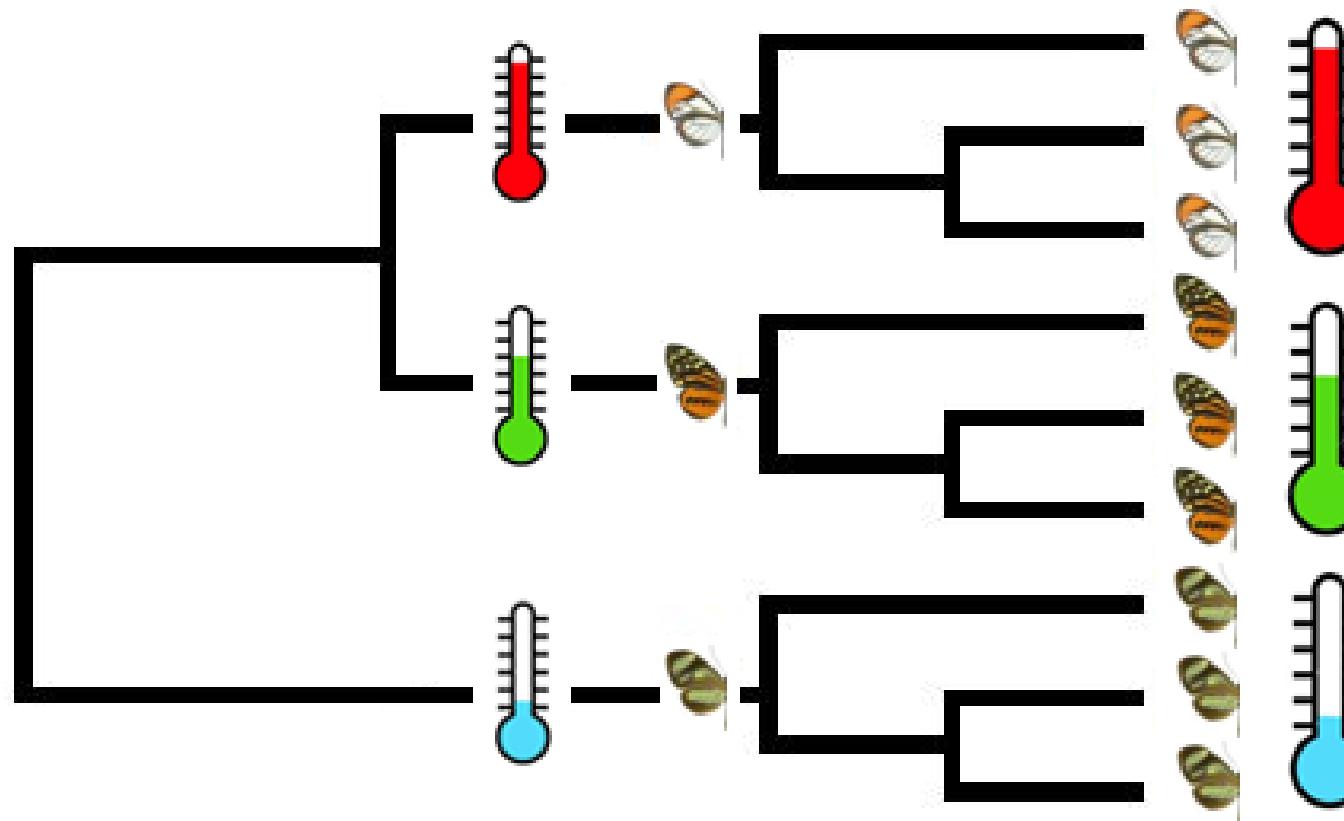
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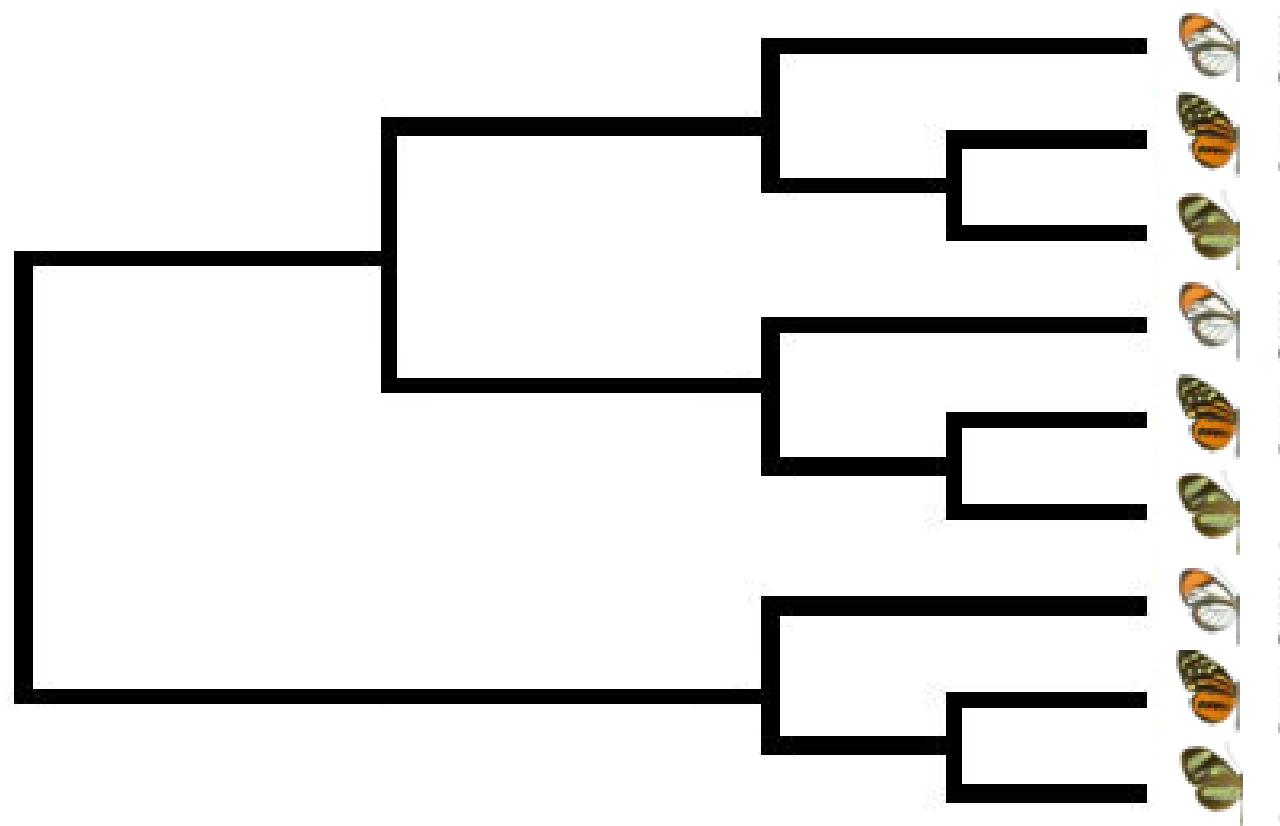
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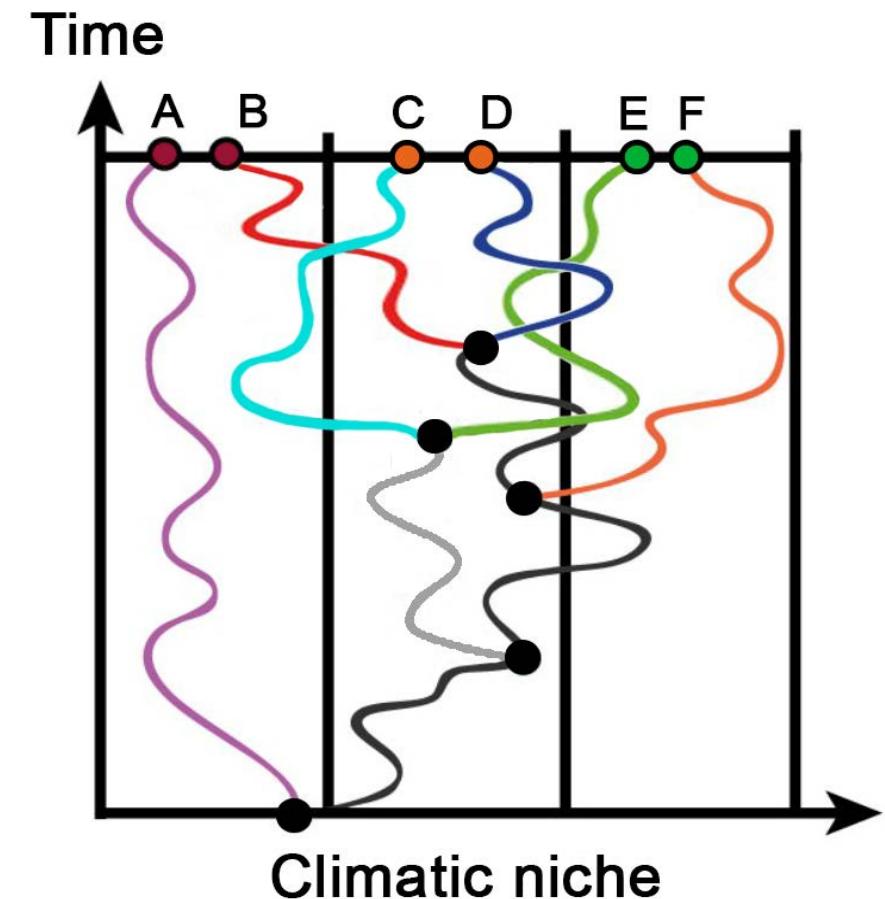
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Simulate the evolution of climatic niche under multivariate **neutral evolutionary model**

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

**Conclusion:**

- Evolutionary association between climatic niche and mimicry patterns
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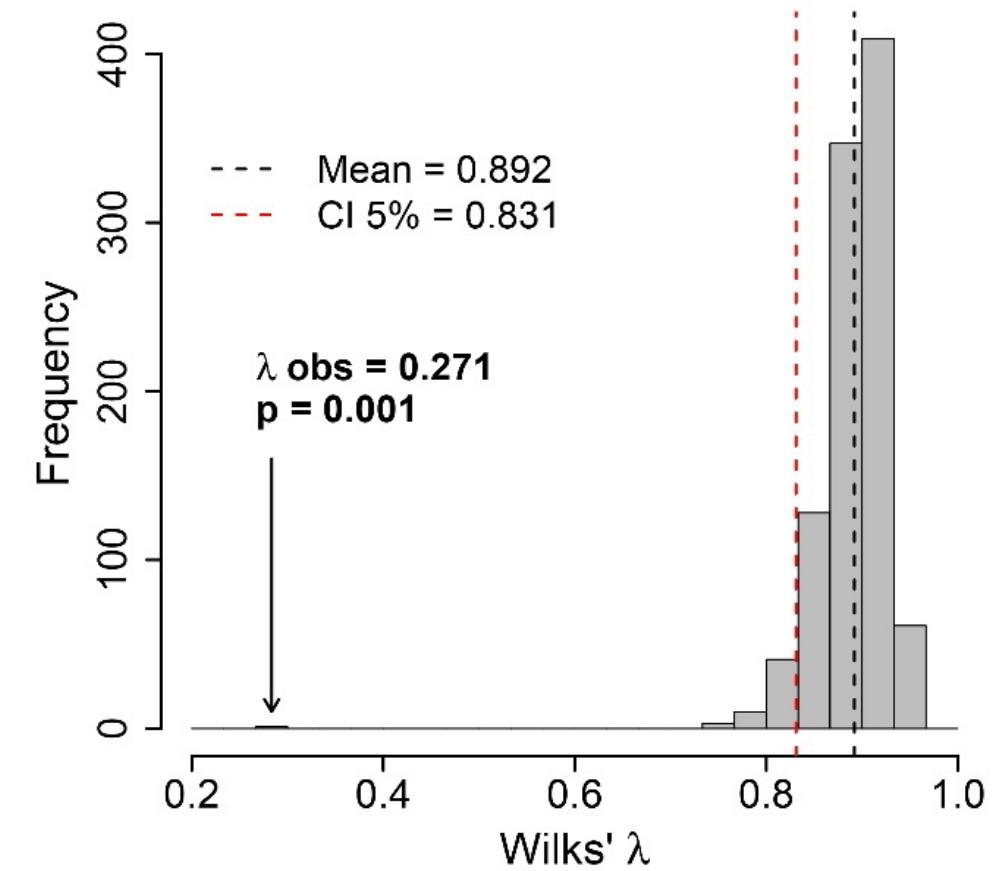
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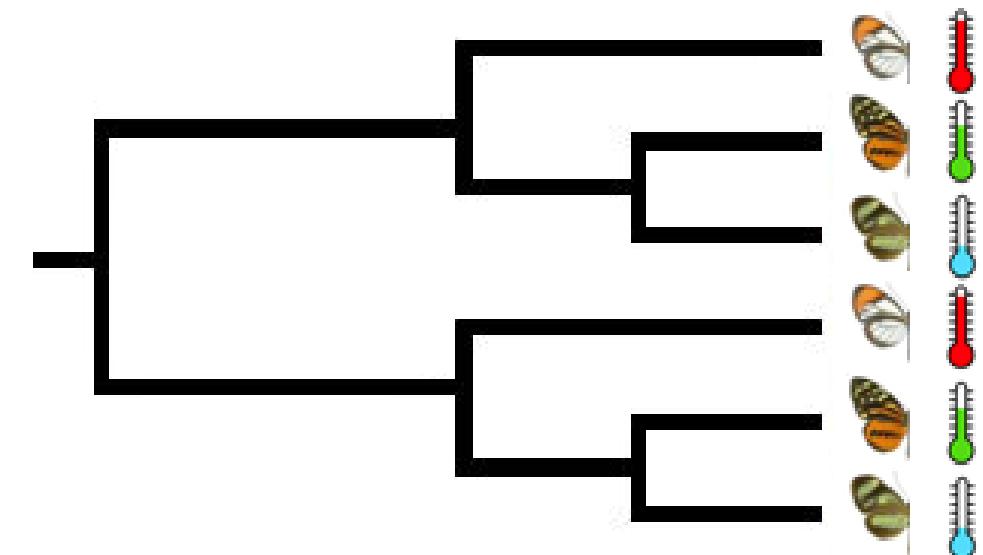


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# Mechanistic scenario

**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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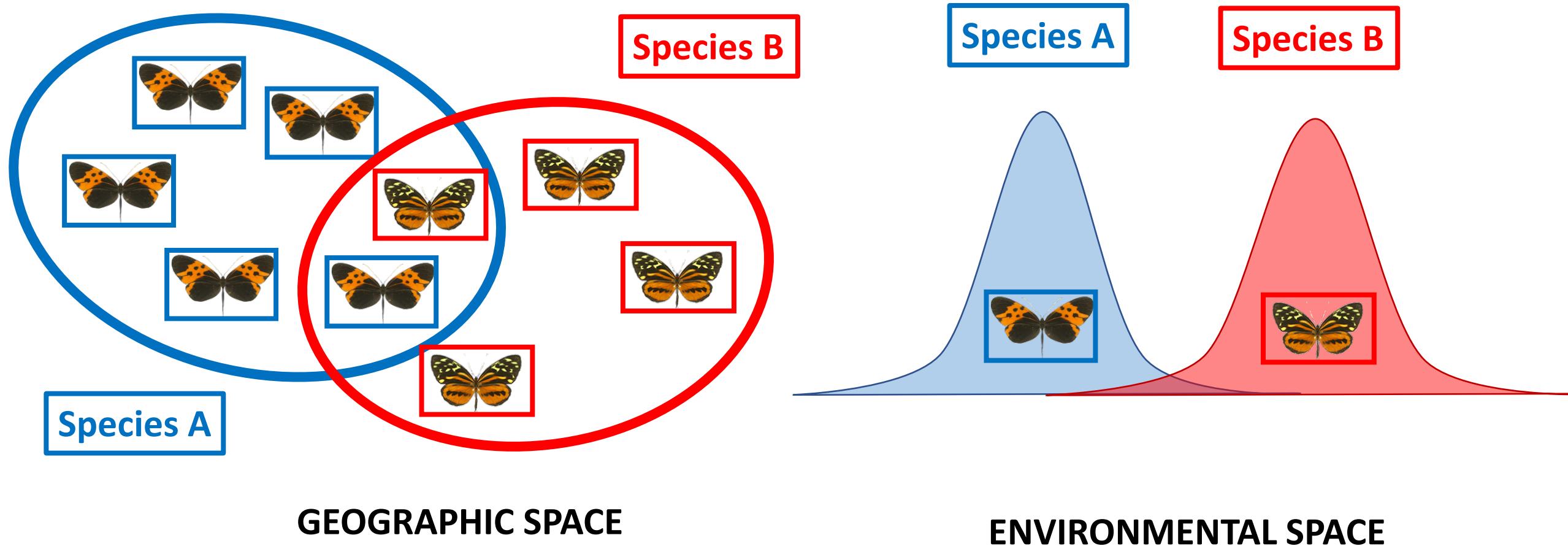
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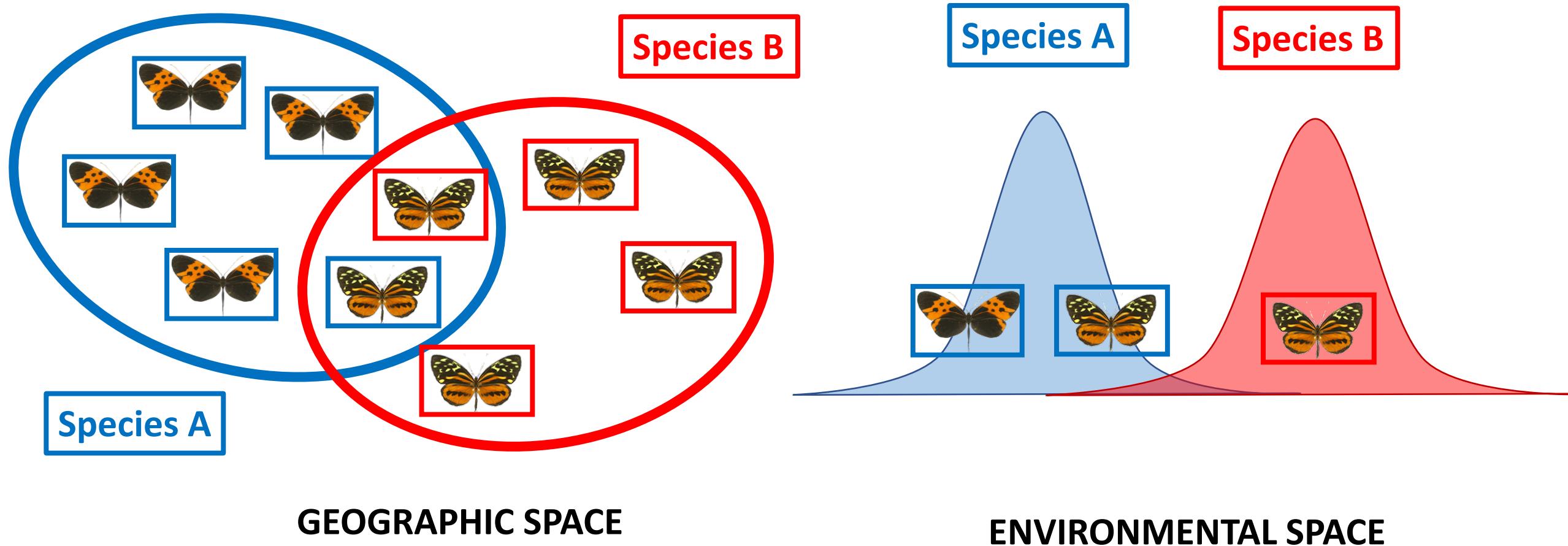
# Mechanistic scenario

## 1/ Initial partial overlap



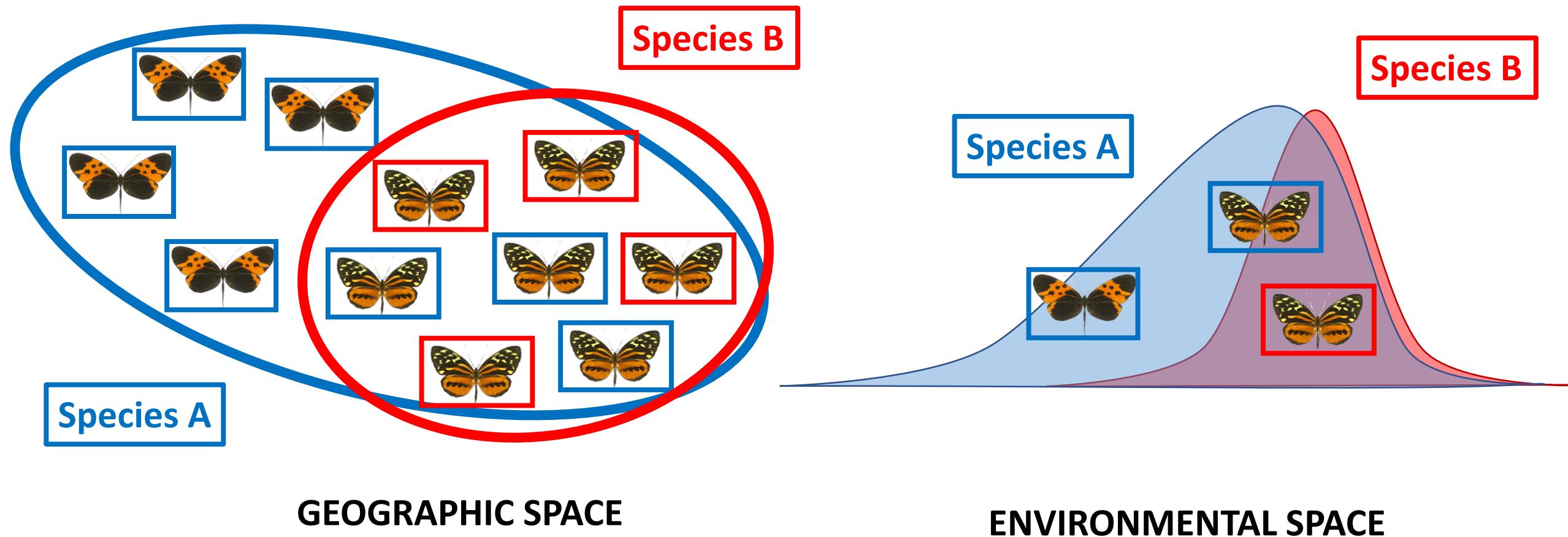
# Mechanistic scenario

## 2/ Pattern convergence



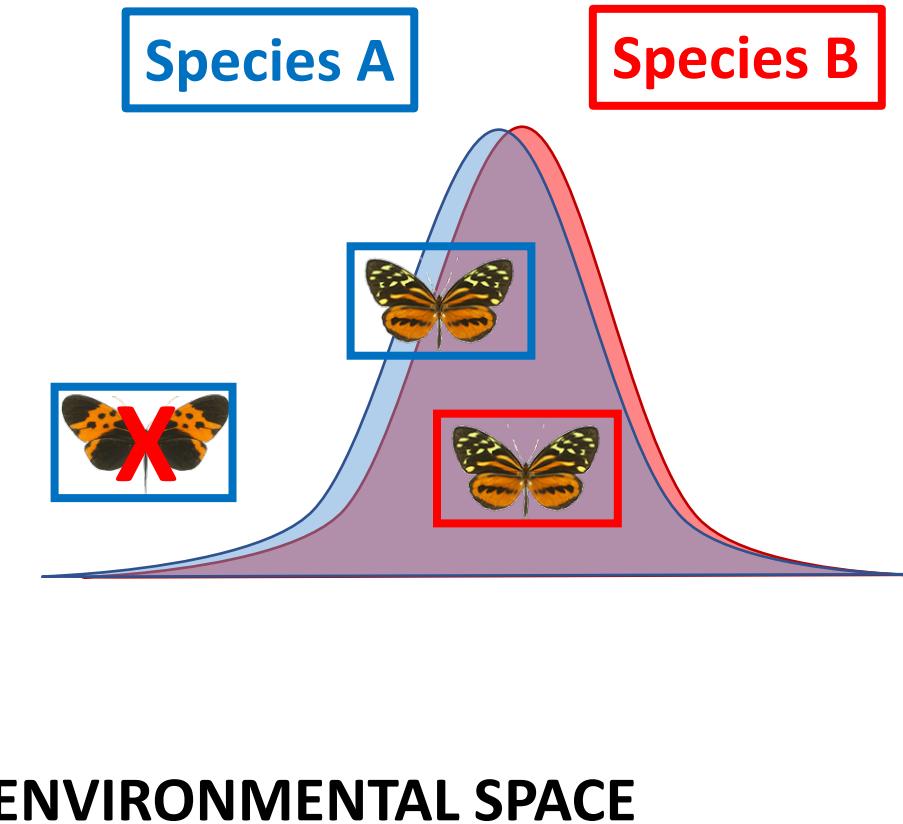
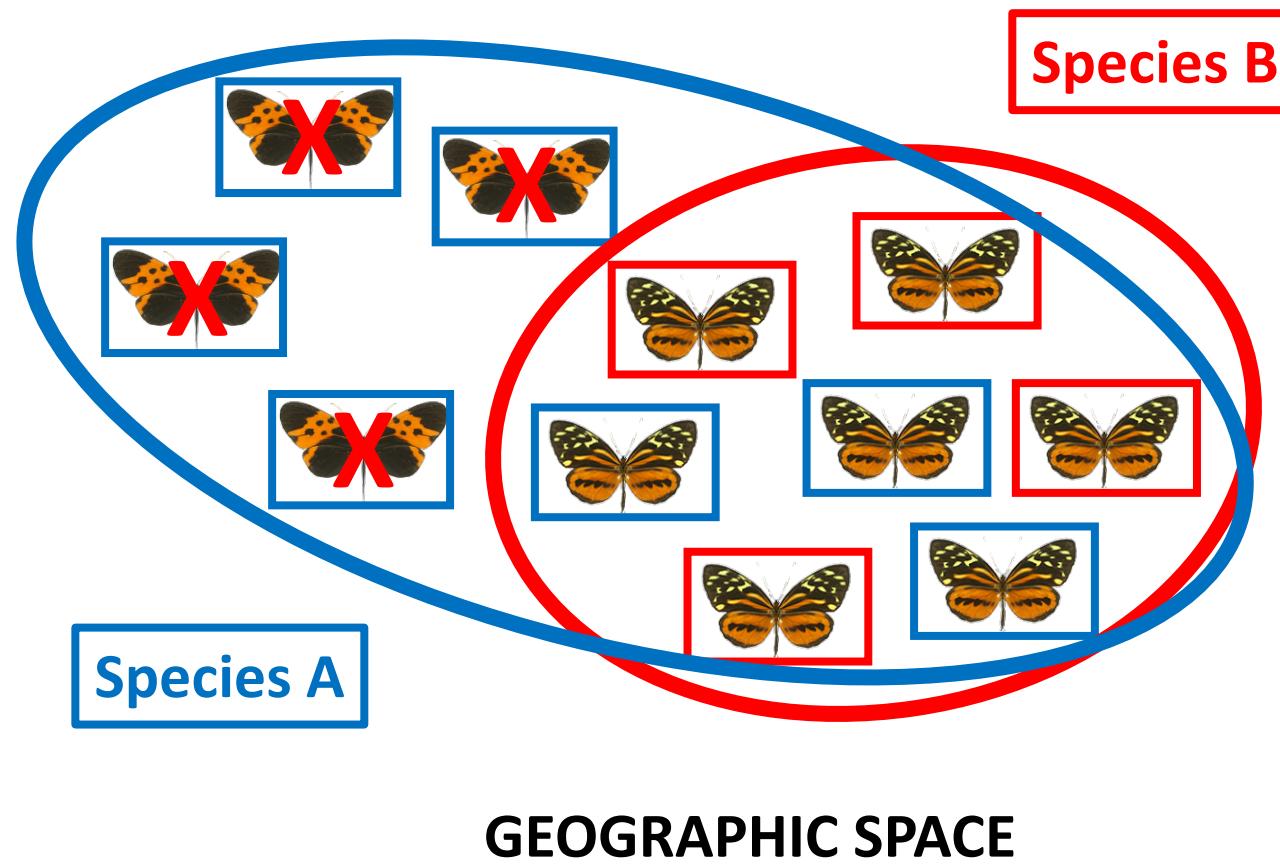
# Mechanistic scenario

## 3/ Niche expansion



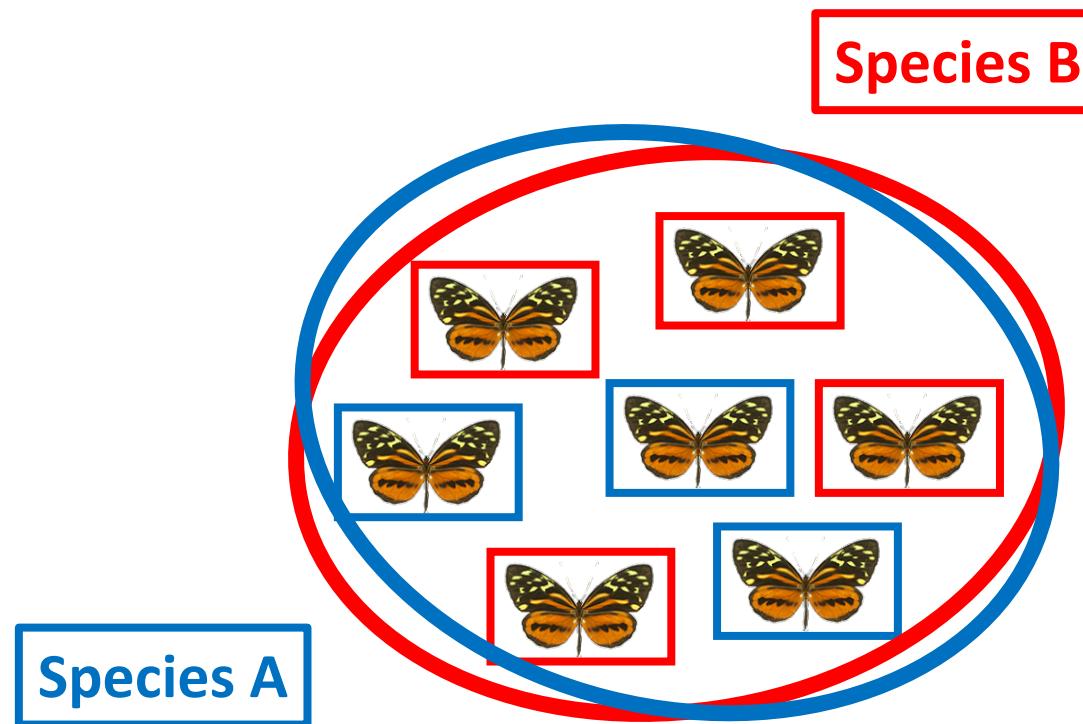
# Mechanistic scenario

## 4/ Niche thinning

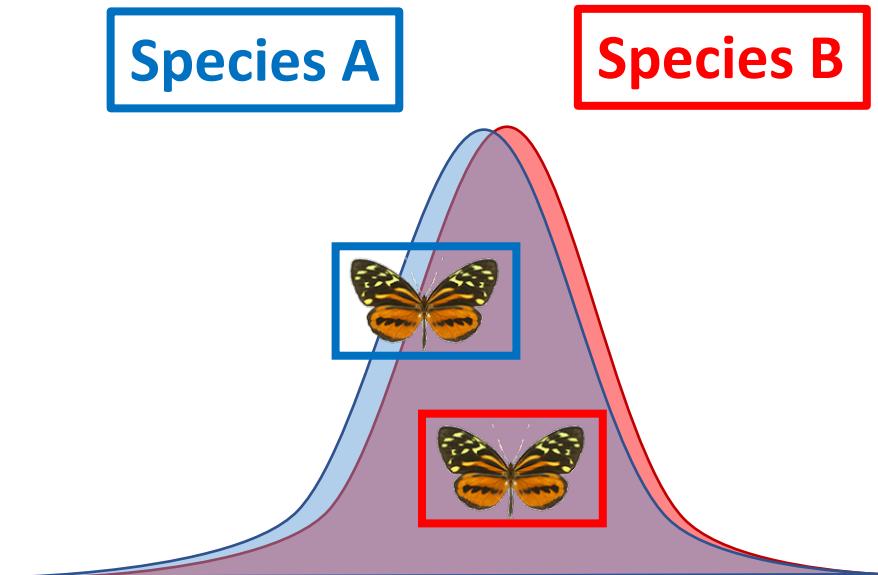


# Mechanistic scenario

## 5/ Final overlap



GEOGRAPHIC SPACE



ENVIRONMENTAL SPACE

# Perspectives

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

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

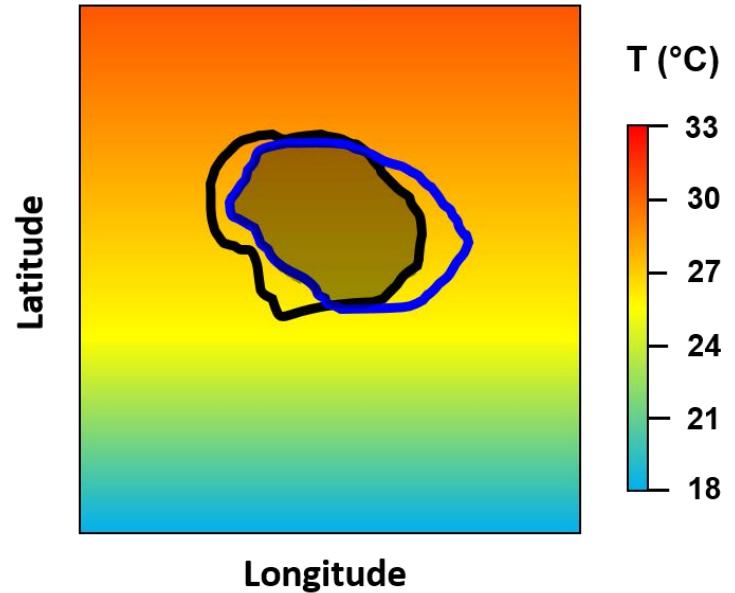
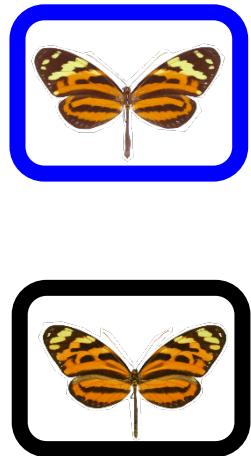
Which response to **climate change**?

# Perspectives

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Which response to **climate change**?

**Cohesion?**

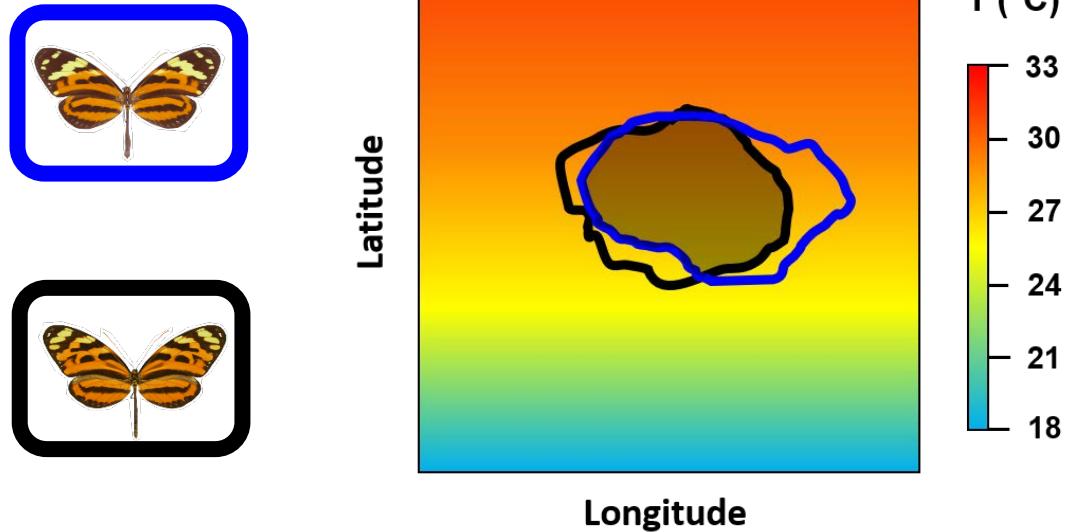


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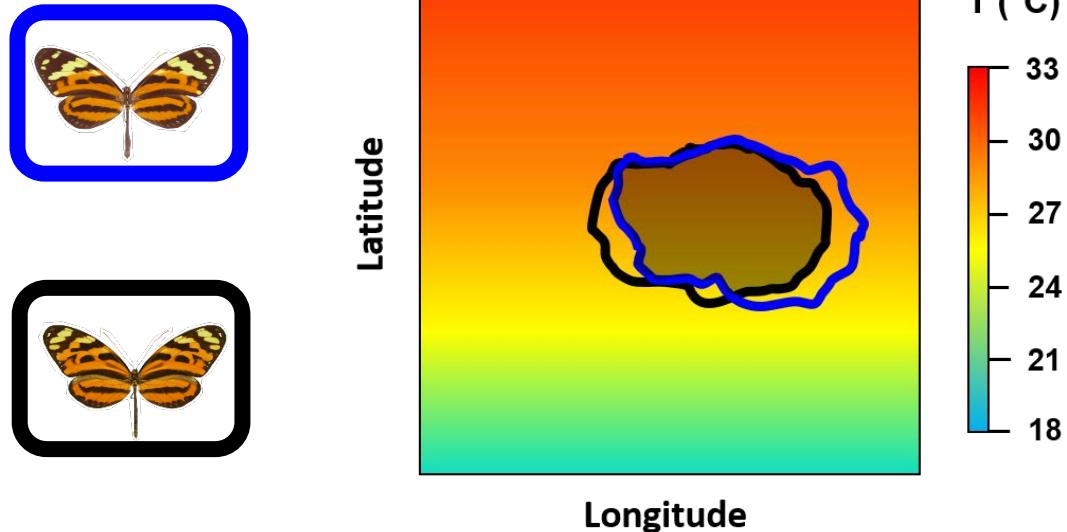


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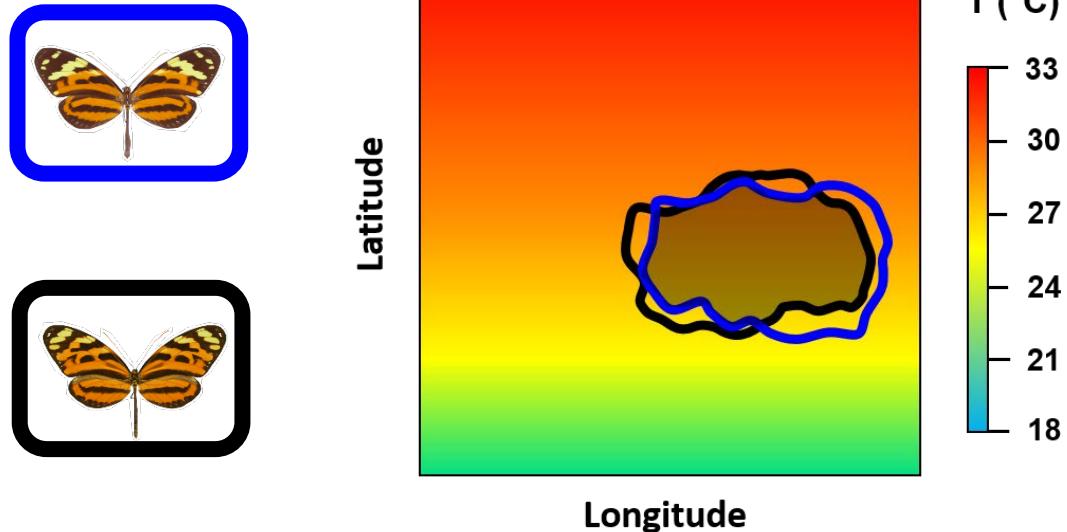


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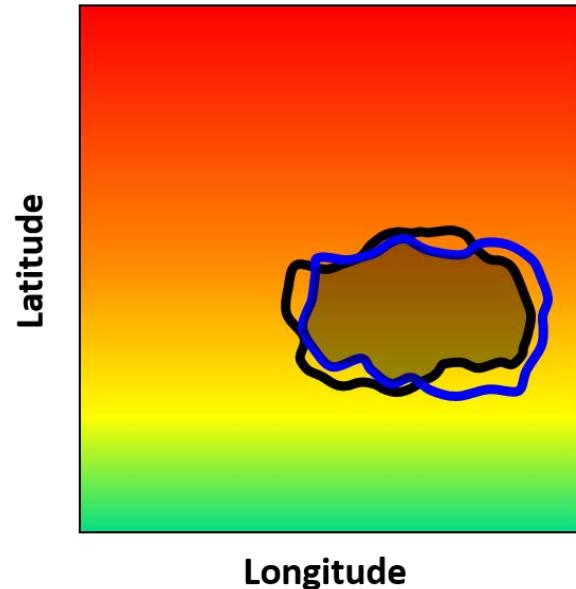
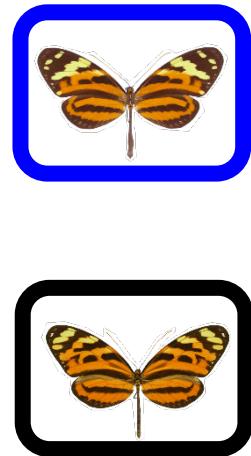


# Perspectives

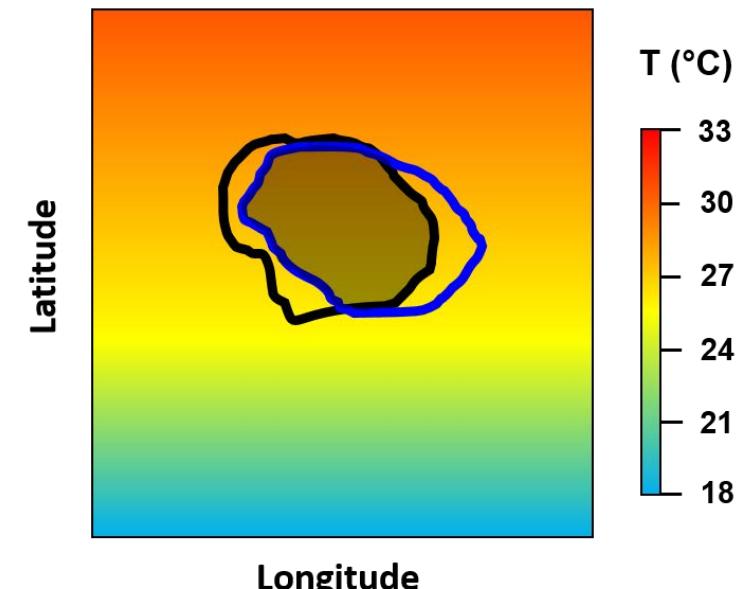
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**Disassembly?**



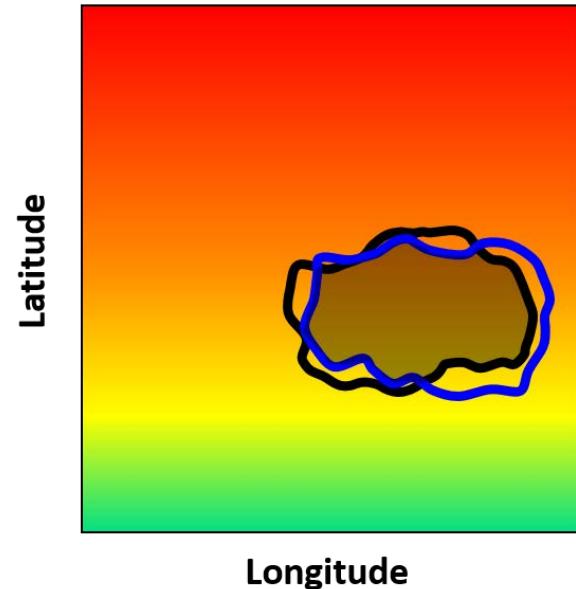
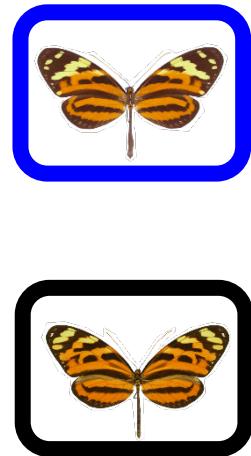
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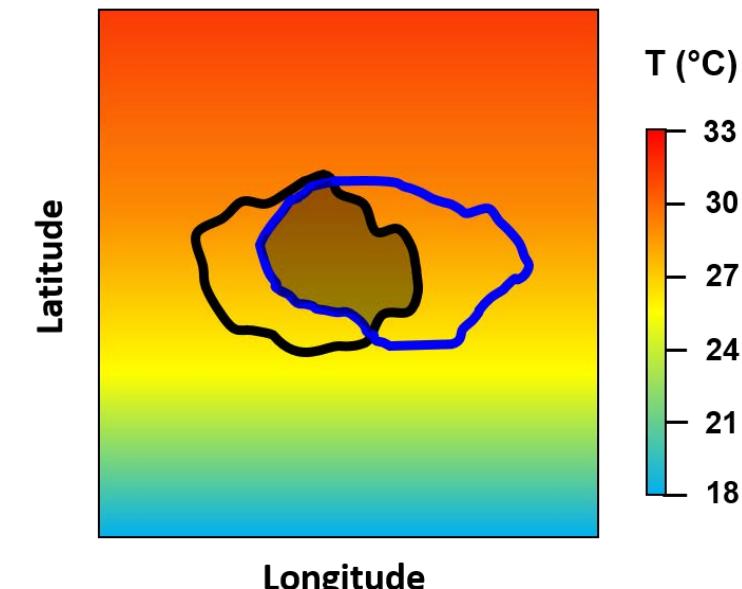
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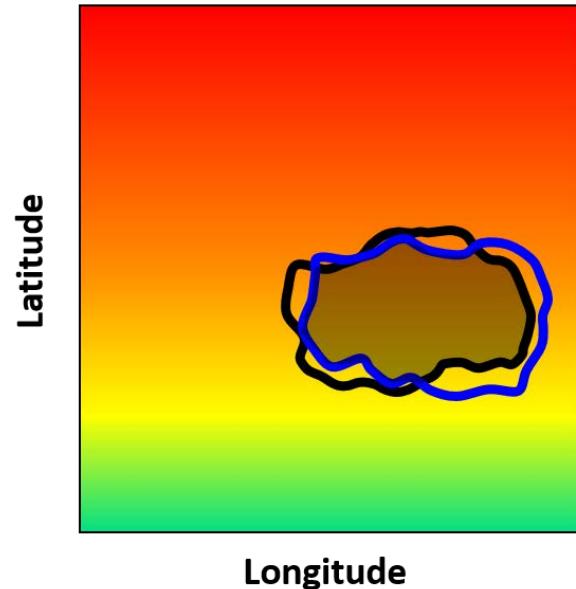
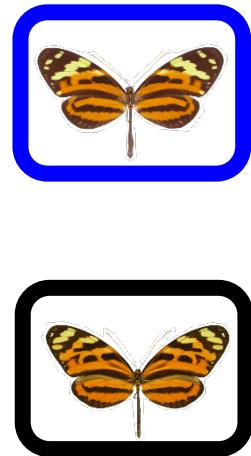


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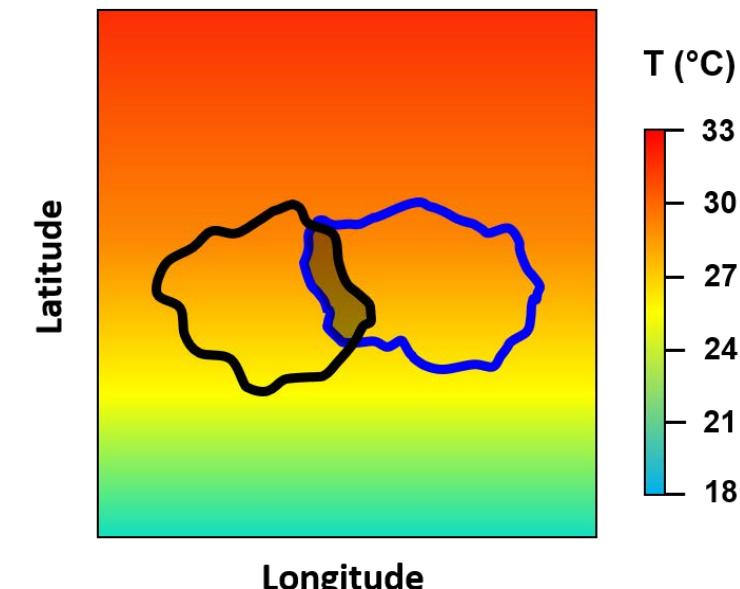
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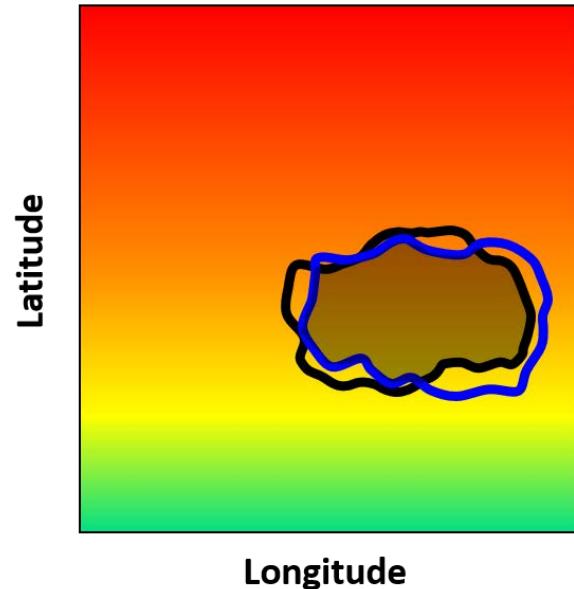
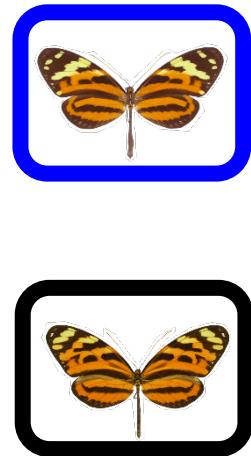


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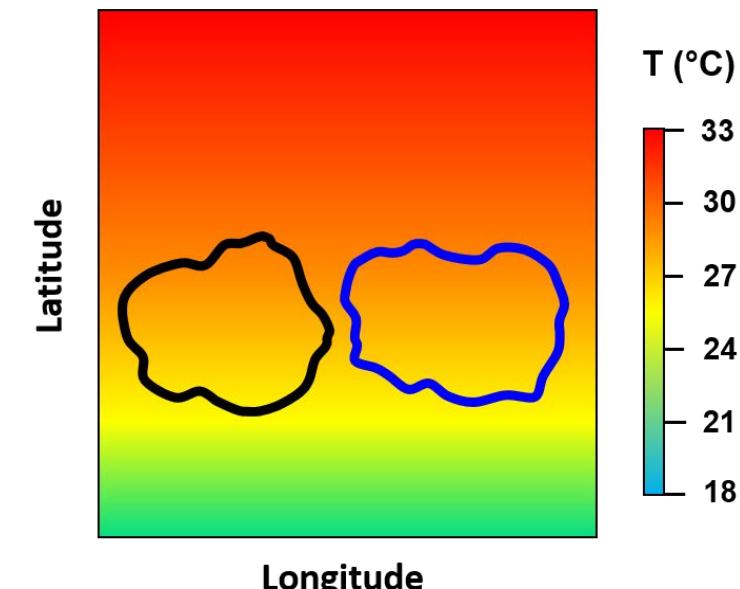
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# Perspectives

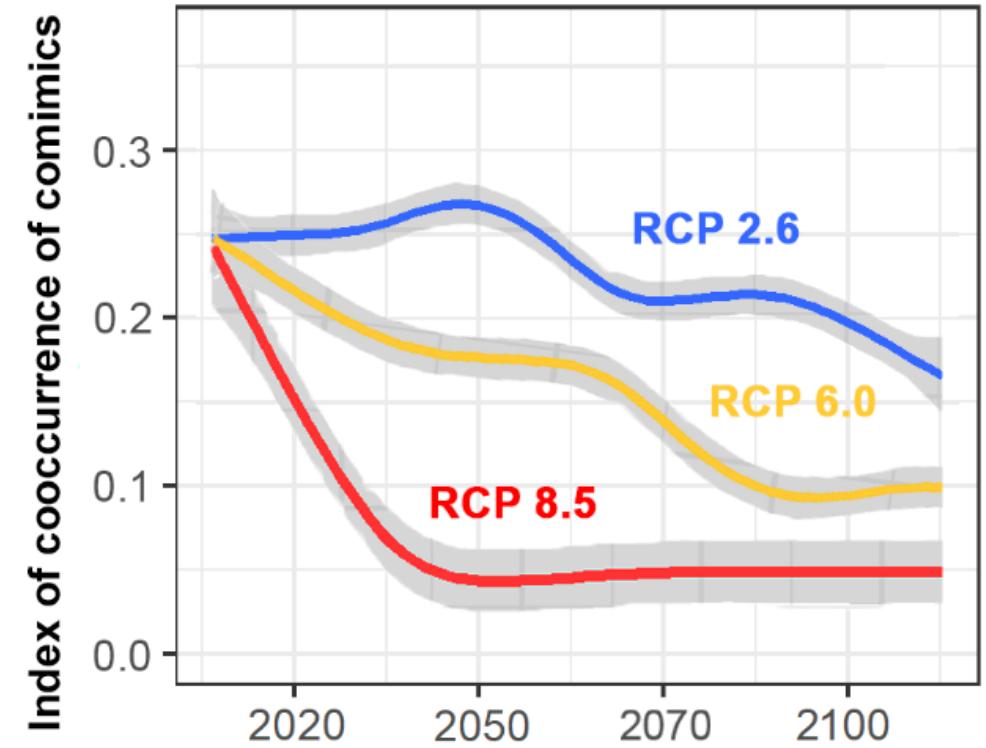
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Which response to **climate change**?

Model **future distributions**:

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



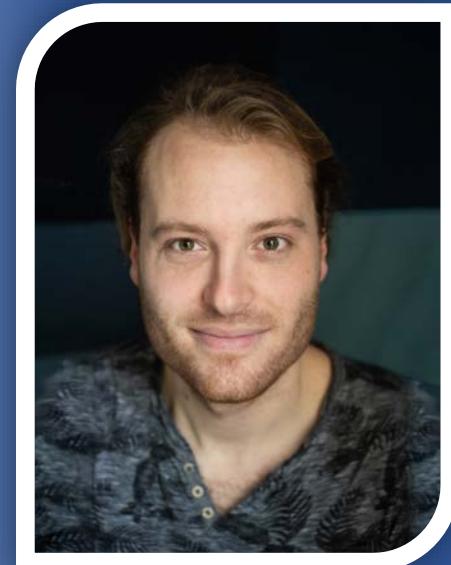
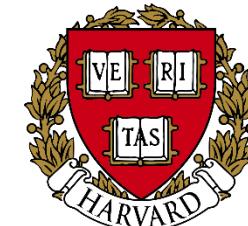
# Research team

**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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SCAN ME

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