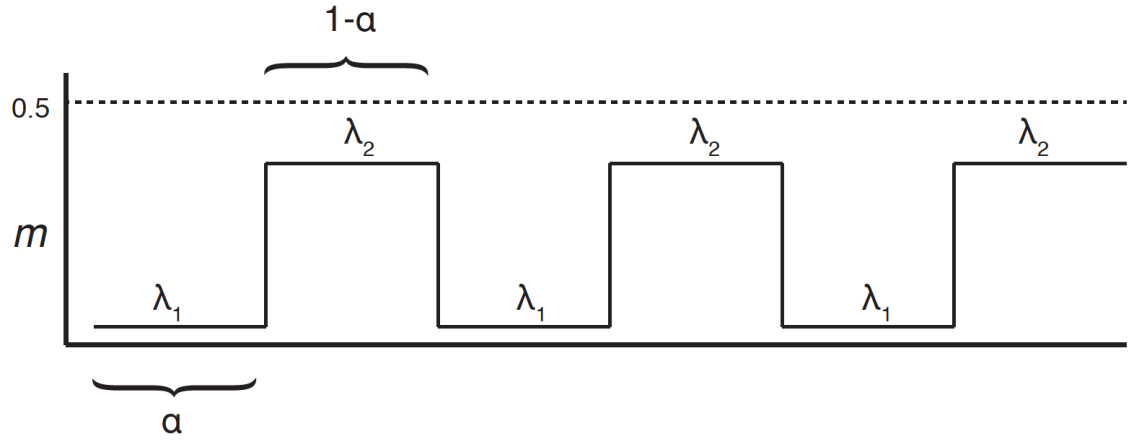
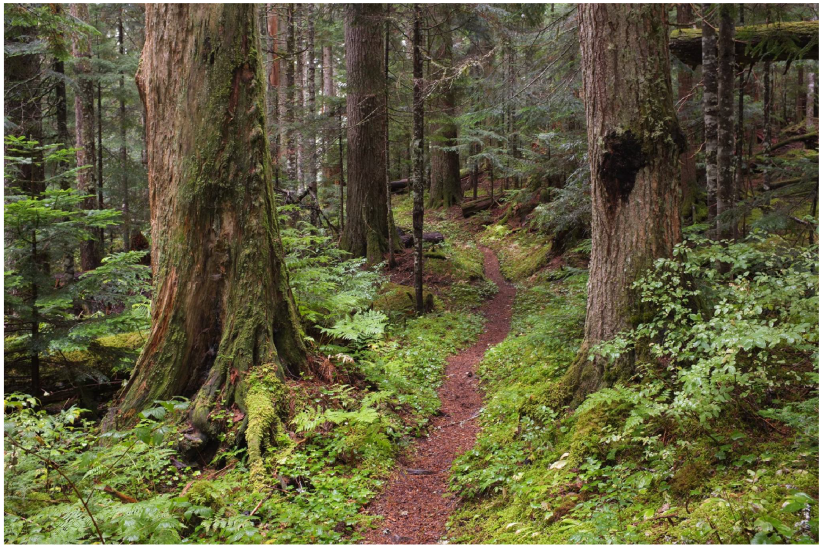


Climate fidelity and genetic variation in mountain landscapes

Ethan B. Linck

University of Wyoming
Department of Zoology & Physiology
@ethanblinck

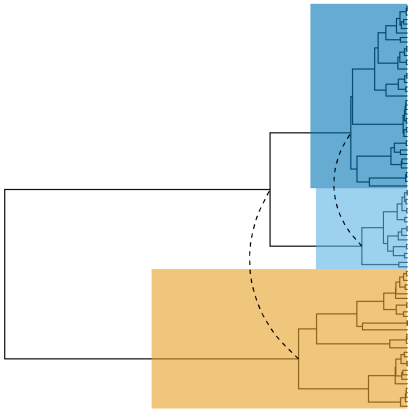
Climate structures biodiversity



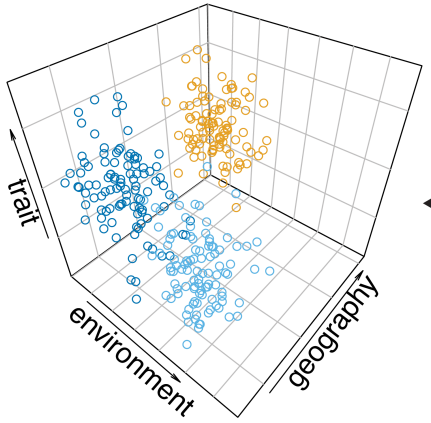
Climate fidelity: the tendency of a species or population to track its climatic niche through time (Wang et al. 2023 *PNAS*)

Integrative population genetics

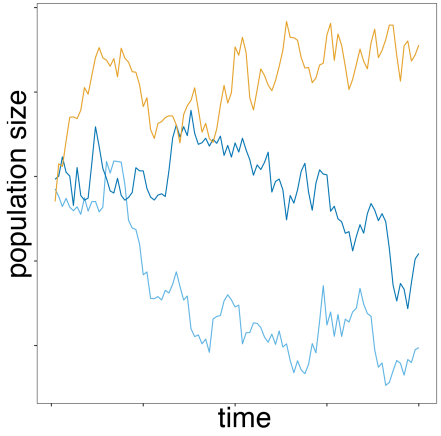
genetic differentiation



species range evolution



global change biology



Linck et al. 2020 *J. Evol. Biol.*

Linck et al. 2019 *Syst. Biol.*

Linck & Battey 2019 *Mol. Ecol. Res.*

Battey, Linck et al. 2018 *Am. Nat.*

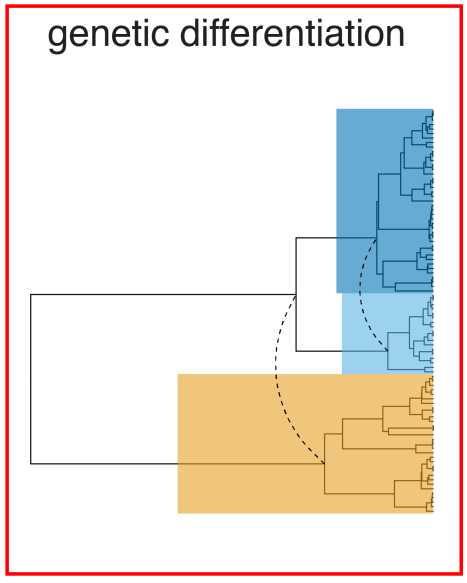
Linck et al. 2023 *Am. Nat.*

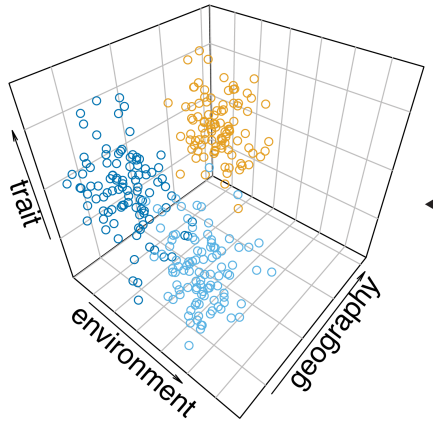
Linck et al. 2020 *Ecol. Evol.*

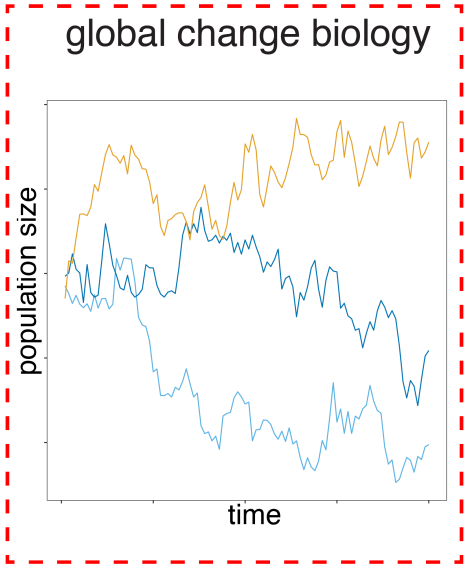
Linck et al. 2021 *Biol. Lett.*

Mamantov et al. 2023 *Glob. Ecol. Biogeogr*

Integrative population genetics







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Linck et al. 2023 *Am. Nat.*

Linck et al. 2020 *Ecol. Evol.*

Linck et al. 2021 *Biol. Lett.*

Mamantov et al. 2023 *Glob. Ecol. Biogeogr*

How do mountains and climate fidelity act to structure genetic variation?

What, if anything, can we do with this information on a burning planet?

Outline

- Q_1: How has climate fidelity shaped genetic variation in Western *Empidonax* flycatchers?
- Q_2: What can we learn from adding climatic complexity to population genetic models?
- Q_3: How can genomics help us predict vulnerability to climate change?
- Q_4: What does any of this mean for conservation?

Outline

- Q_1: **How has climate fidelity shaped genetic variation in Western *Empidonax* flycatchers?**
- Q_2: What can we learn from adding climatic complexity to population genetic models do?
- Q_3: How can genomics help us predict vulnerability to climate change?
- Q_4: What does any of this mean for conservation?

Acknowledgements:

- **Collaborators**: Kevin Epperly, Paul van Els, Garth Spellman, Rob Bryson, John McCormack, **Ricardo Canales-del-Castillo**, John Klicka, **Alex Hopping**
- **Funding**: Department of Defense NDSEG Fellowship

Climatic cycles shape biodiversity

GLACIATION, A FACTOR IN SPECIATION

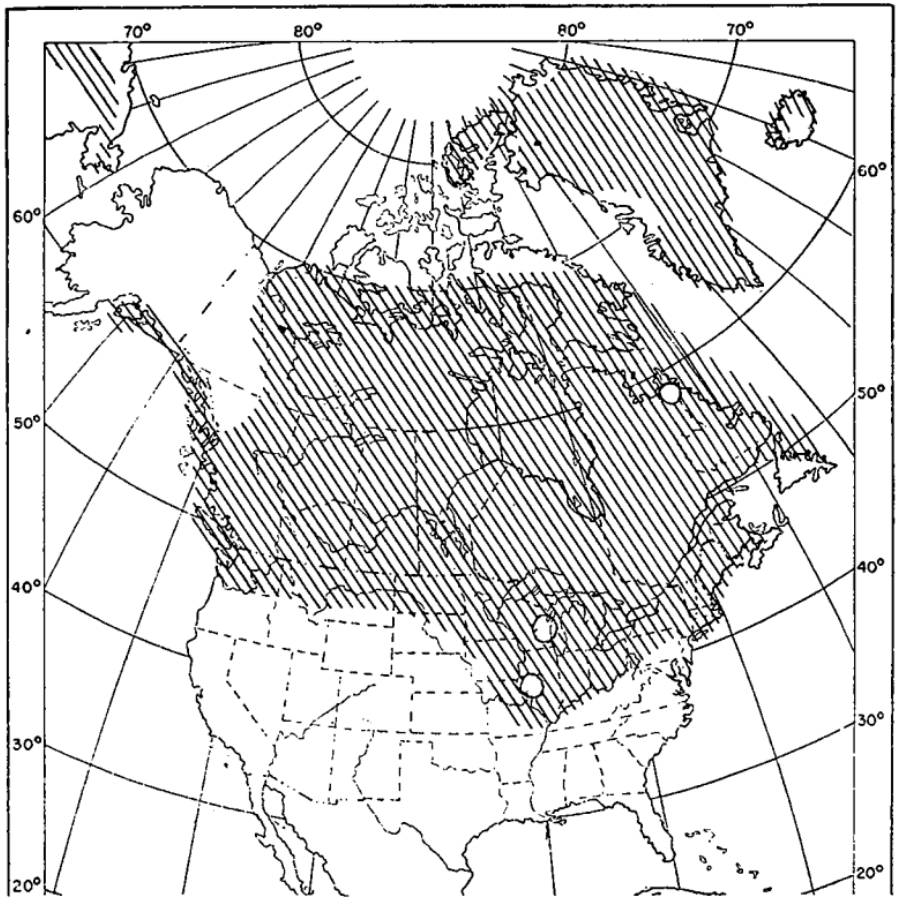
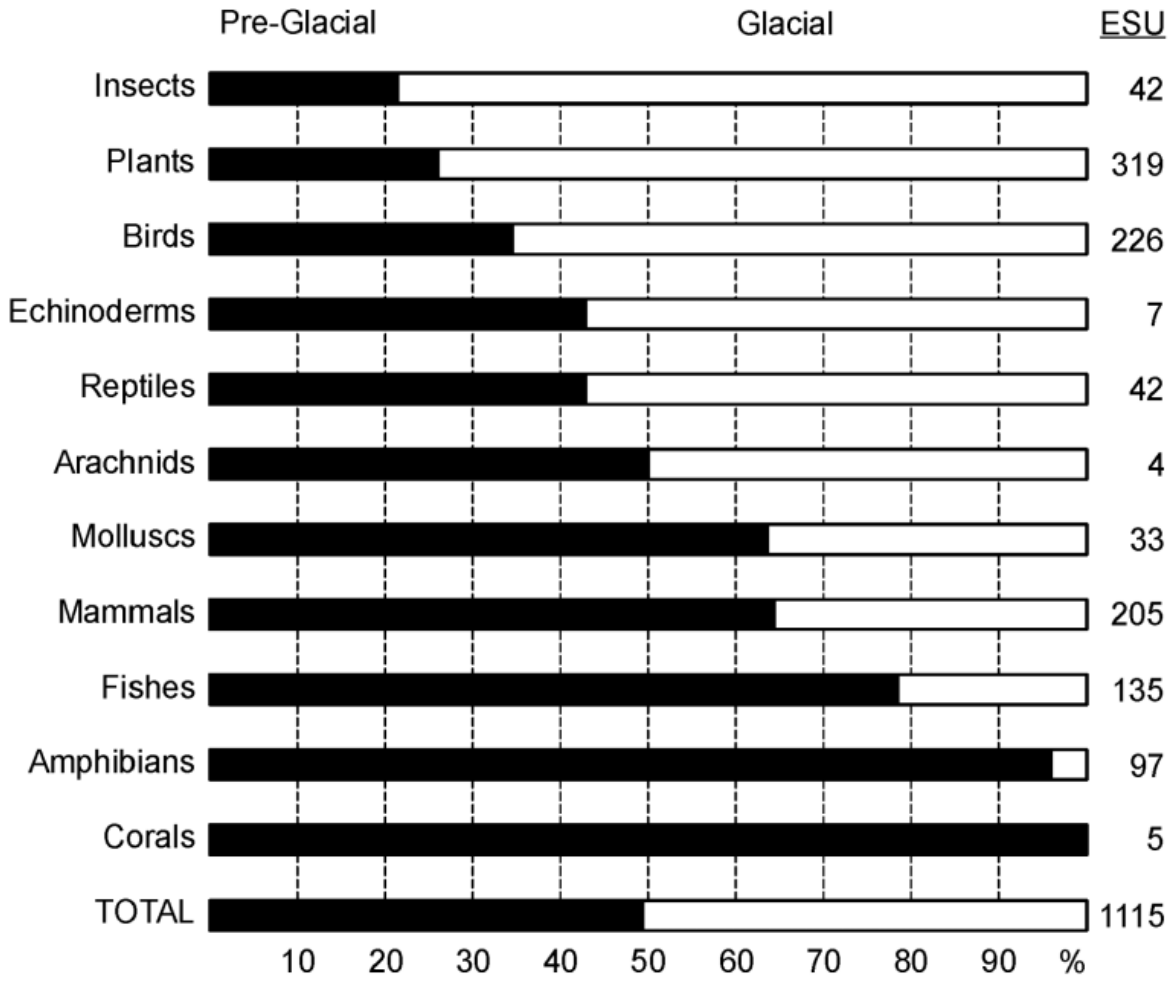


FIG. 1. Maximum extent of solid ice sheets according to Hulten, 1937; additional local glaciation also occurred. Flint (see fig. 2) believes that glaciation was more extensive than this.

(Rand 1948 *Evolution*)

Climatic cycles shape biodiversity



(Rull 2008 *Molecular Ecology*)

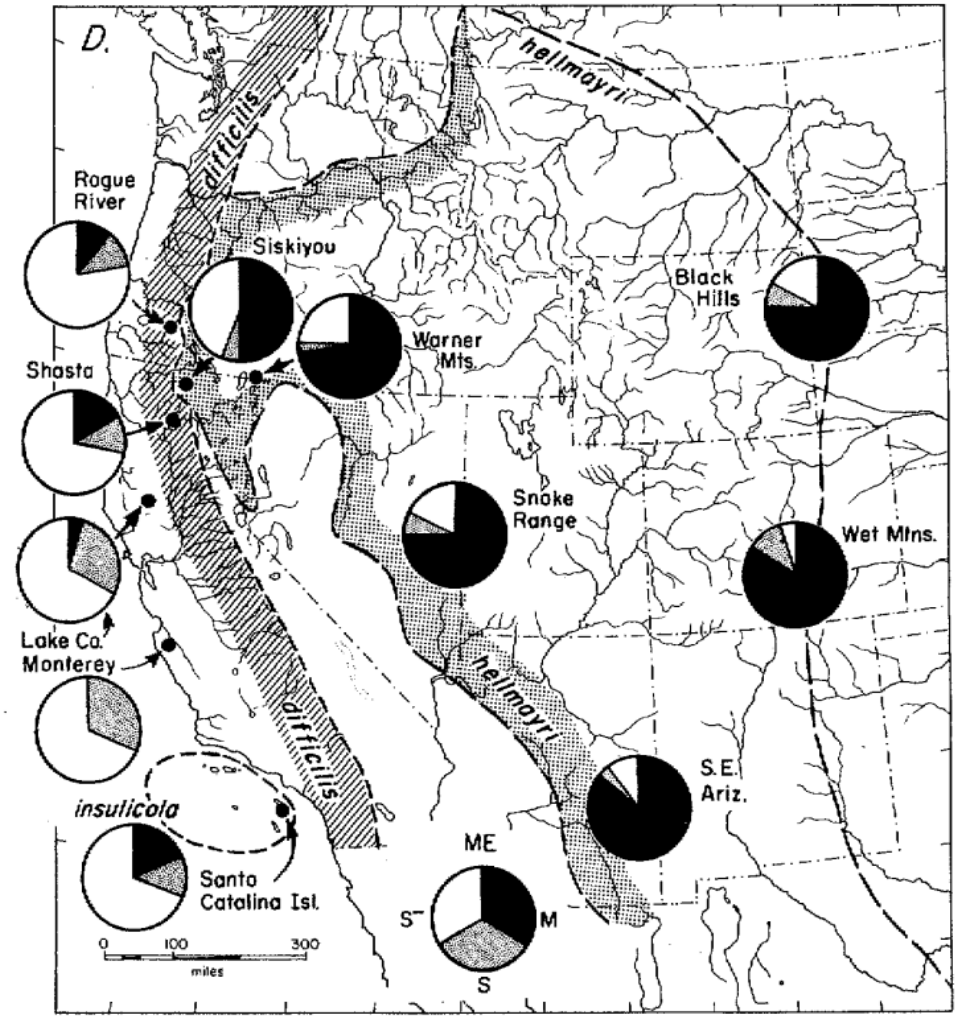
"Western" *Empidonax* Flycatchers

Cordilleran Flycatcher (COFL)
Empidonax occidentalis

Pacific-slope Flycatcher (PSFL)
Empidonax difficilis

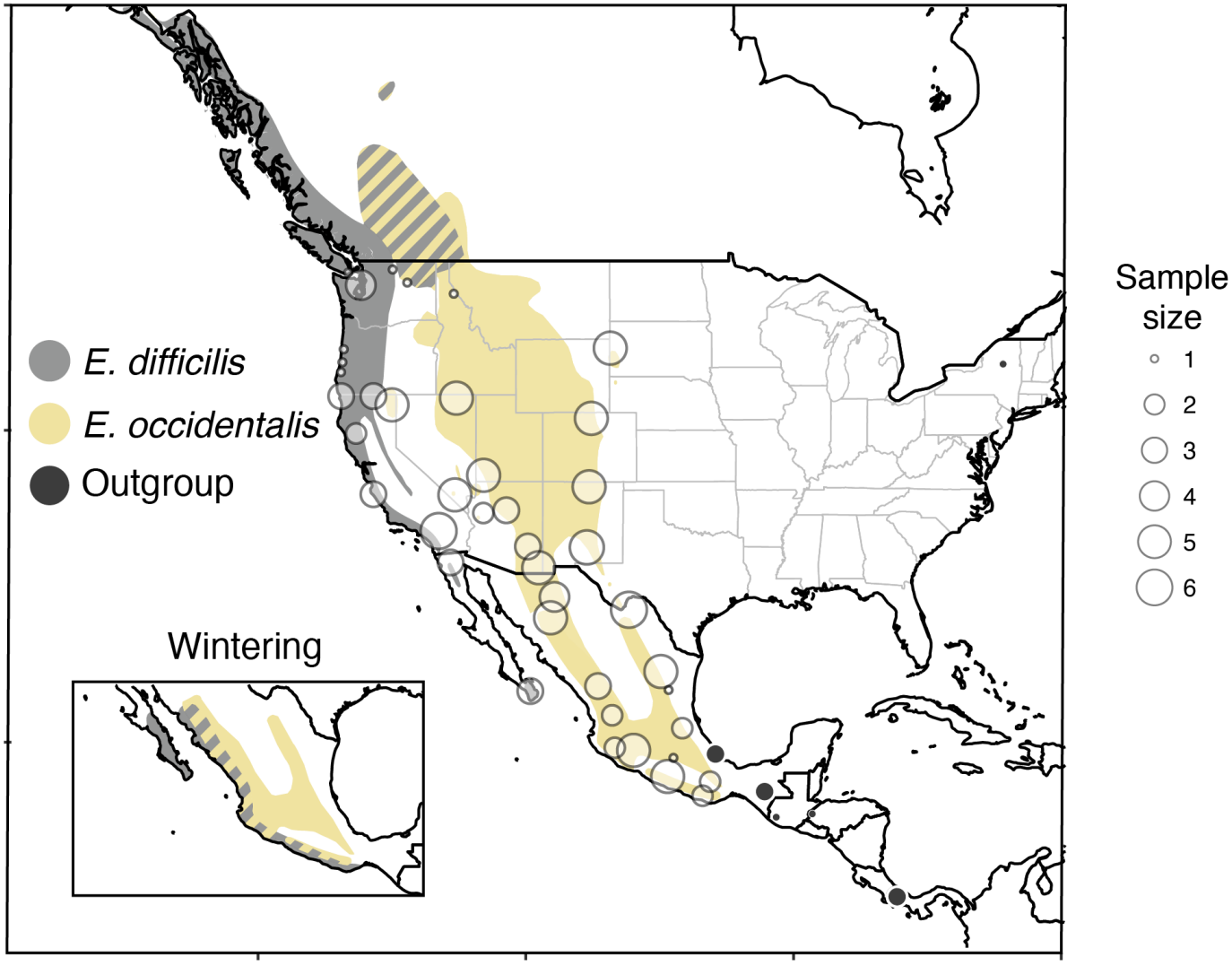
(Macaulay Library 109315481 & 236799211)

One species or two?



(Johnson & Marten 1988 *Auk*)

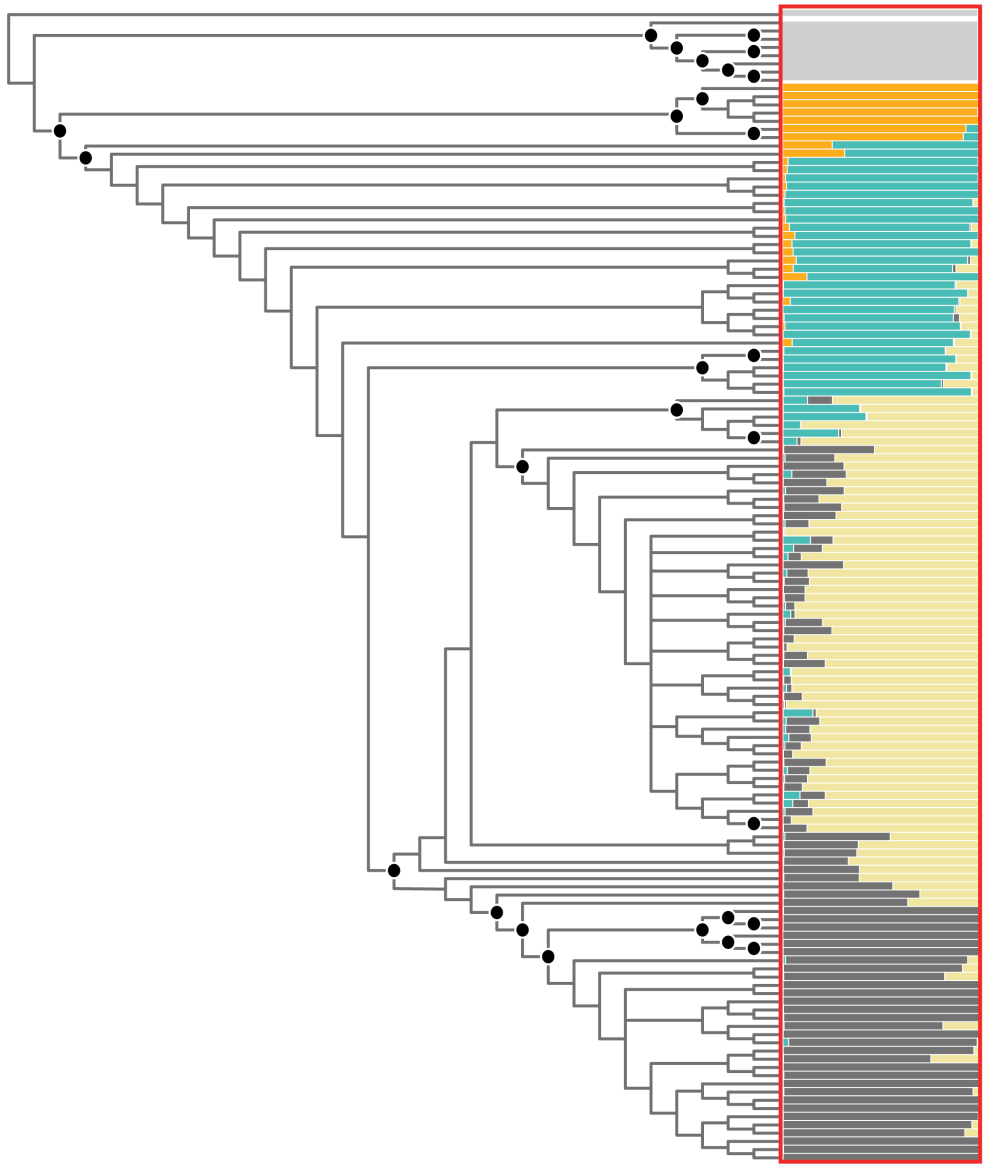
New information, more genes, more geography



(Linck et al. 2019 *Syst. Biol.*)

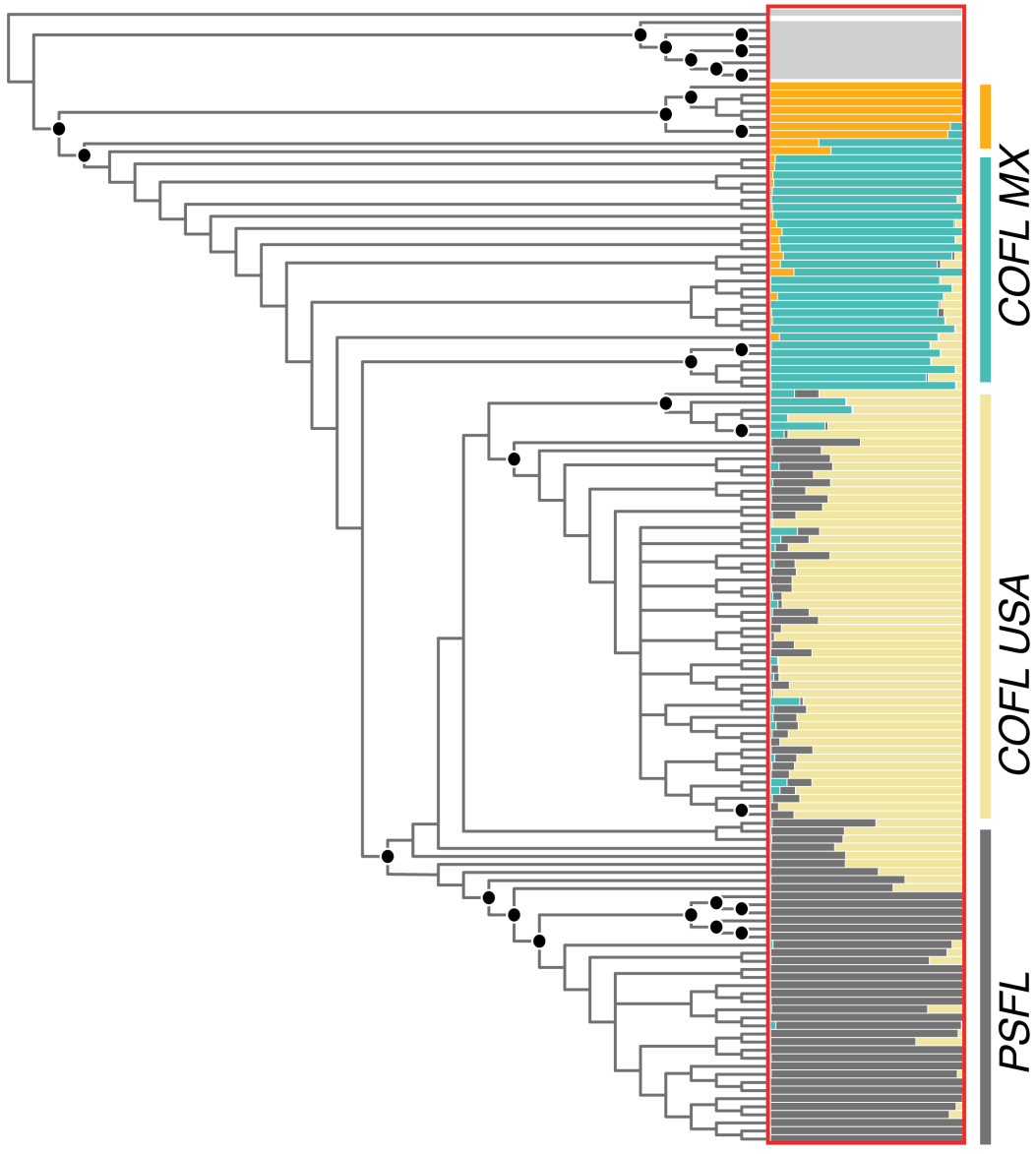
H_1: Mountain ranges structure genetic variation in Western *Empidonax*

Geographically structured populations



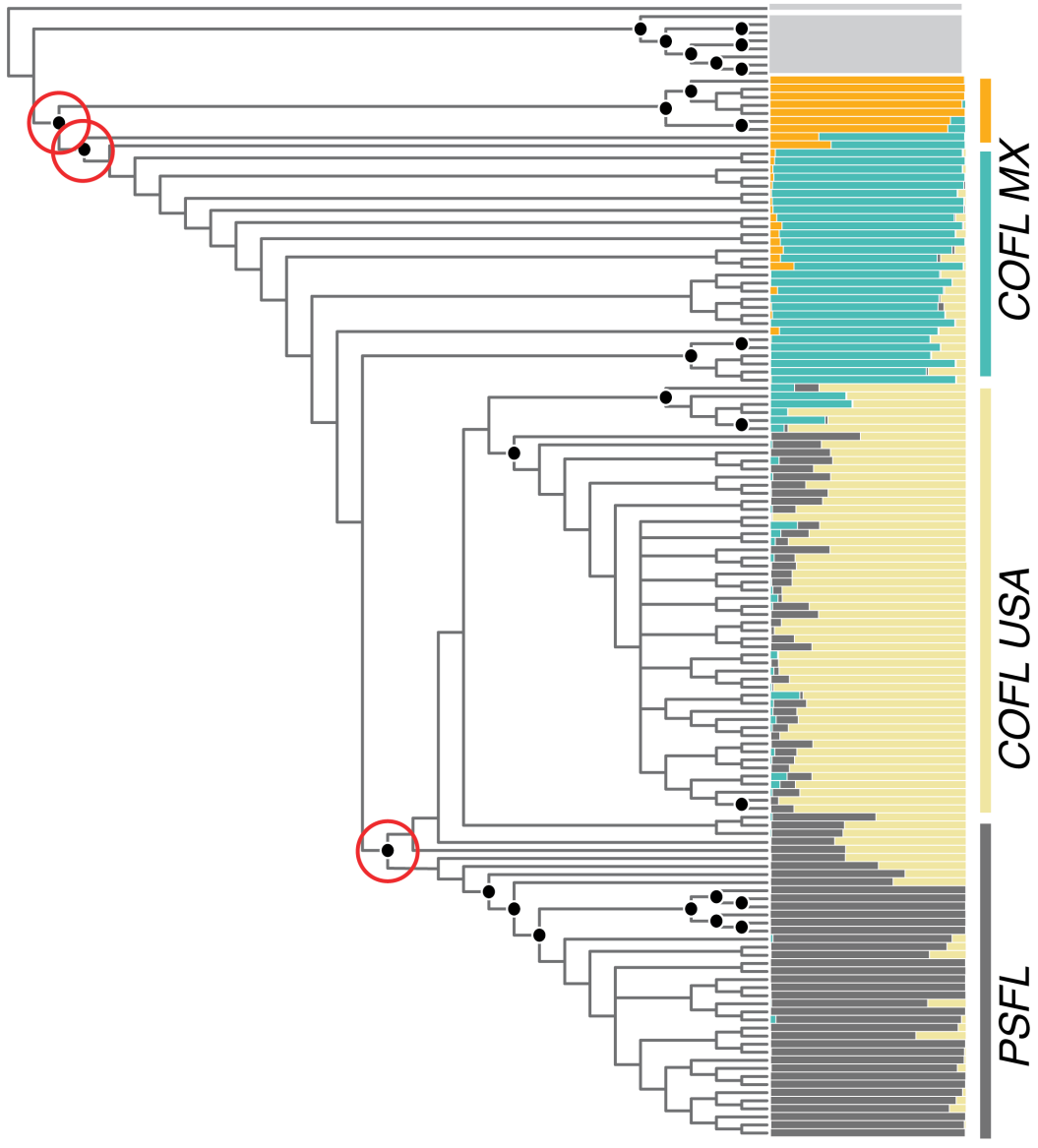
(Linck et al. 2019 *Syst. Biol.*)

Geographically structured populations



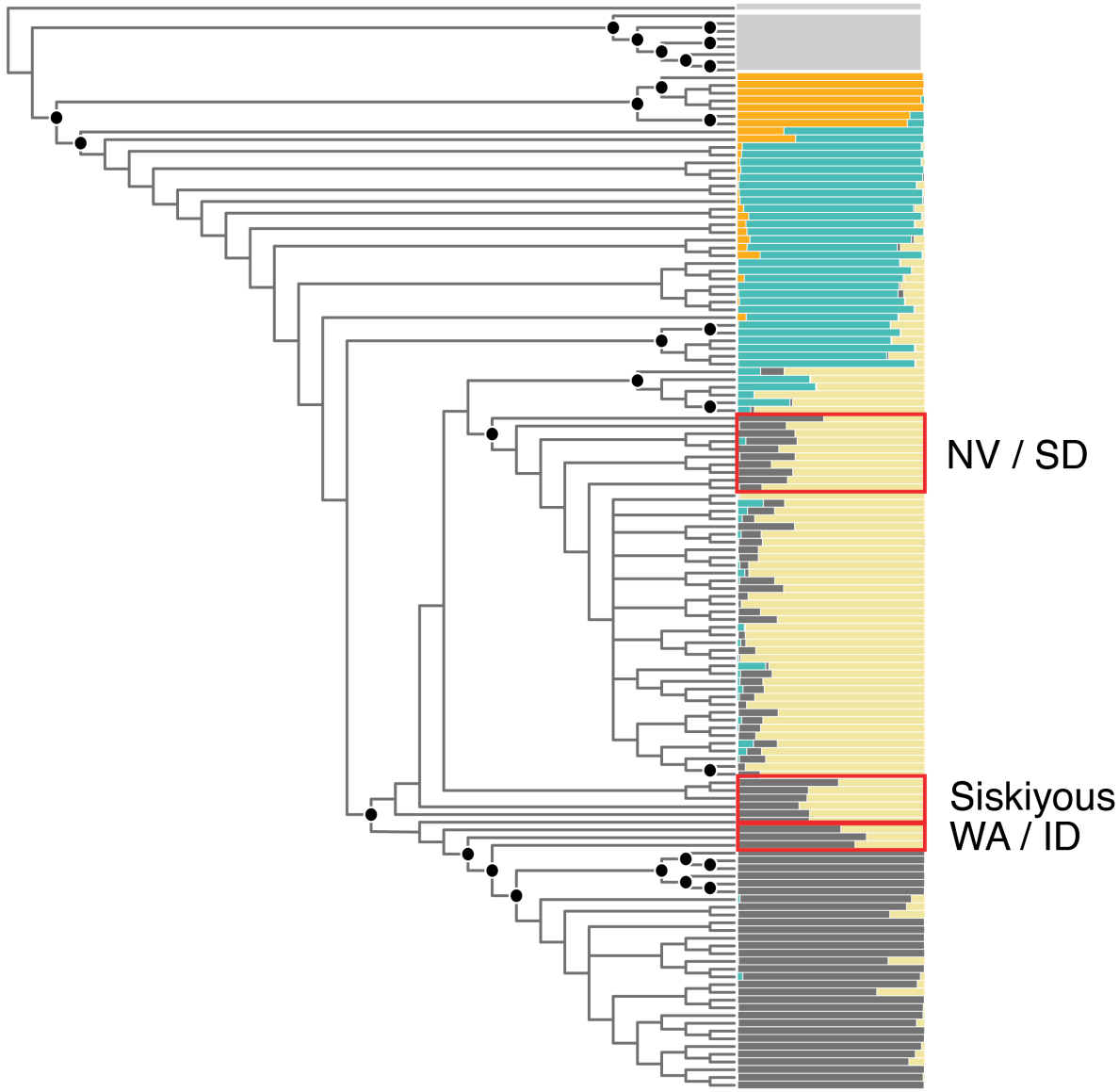
(Linck et al. 2019 *Syst. Biol.*)

COFL is paraphyletic!



(Linck et al. 2019 *Syst. Biol.*)

Hybridization at forest corridors



(Linck et al. 2019 *Syst. Biol.*)

Takeaways

- 1 species of WEFL (for now)
- Hybridization is key
- Climate fidelity and montane geography explain genetic structure in *Empidonax* flycatchers
- **Application:** There's no getting around comprehensive sampling for delimitation of management units

Outline

- Q_1: How has climate fidelity shaped genetic variation in Western *Empidonax* flycatchers?
- Q_2**: What can we learn from adding climatic complexity to population genetic models?**
- Q_3: How can genomics help us predict vulnerability to climate change?
- Q_4: What does any of this mean for conservation?

Acknowledgements:

- **Collaborators**: CJ Battey, Ana Bedoya
- **Funding**: NSF DDIG #1701224

Climatic cycles shape biodiversity

GLACIATION, A FACTOR IN SPECIATION

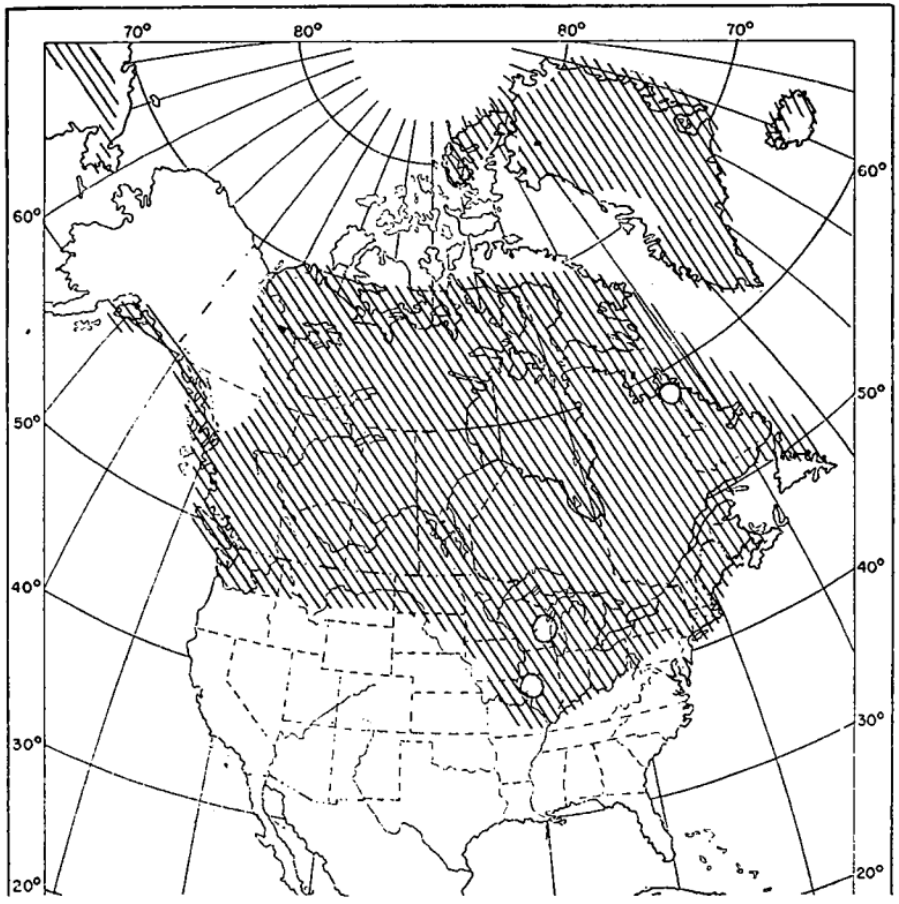
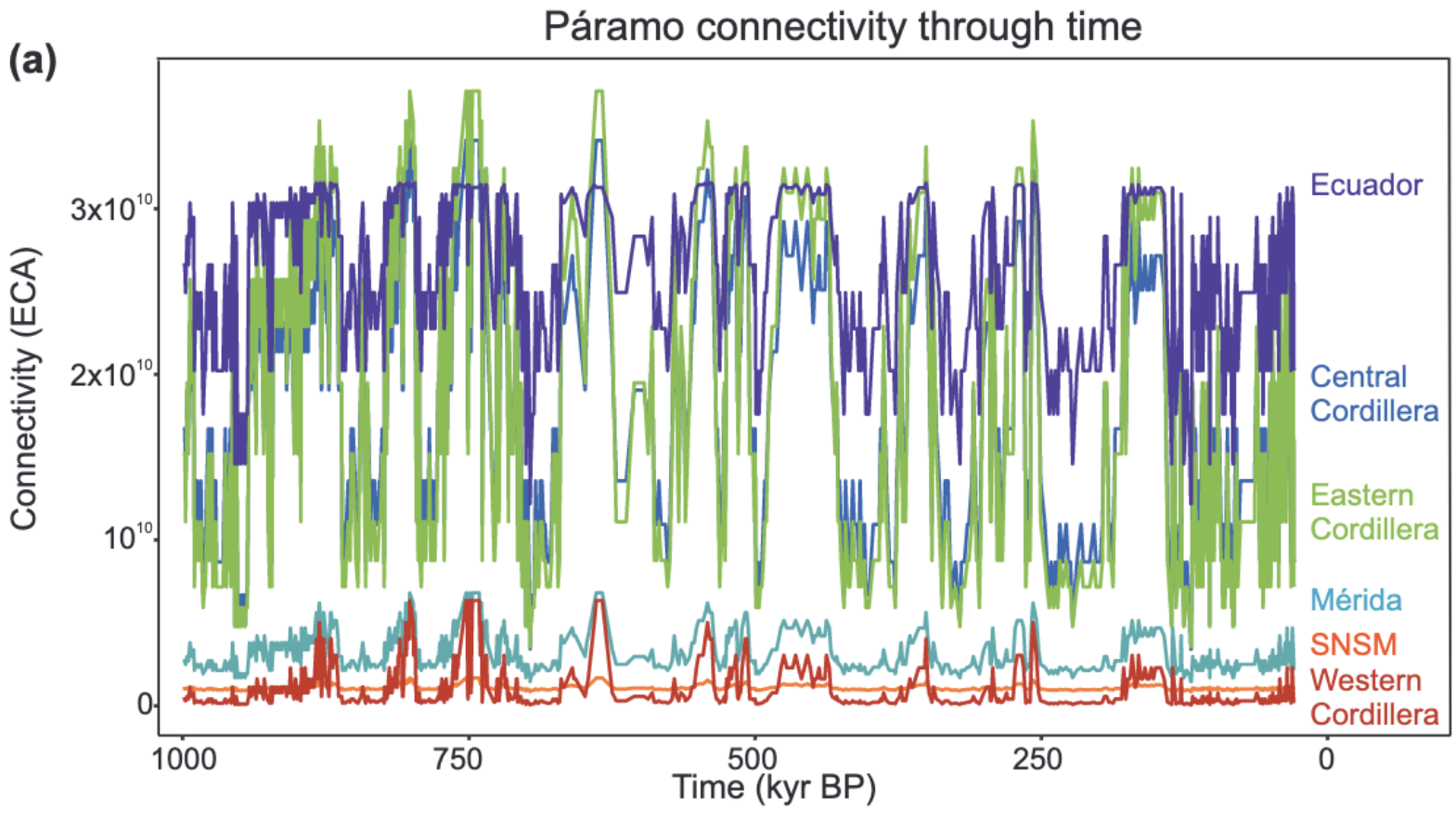


FIG. 1. Maximum extent of solid ice sheets according to Hulten, 1937; additional local glaciation also occurred. Flint (see fig. 2) believes that glaciation was more extensive than this.

(Rand 1948 *Evolution*)

Climate fidelity and cyclical contact



(Flantua et al. 2019 *J. Biogeog.*)

Simple models of divergence

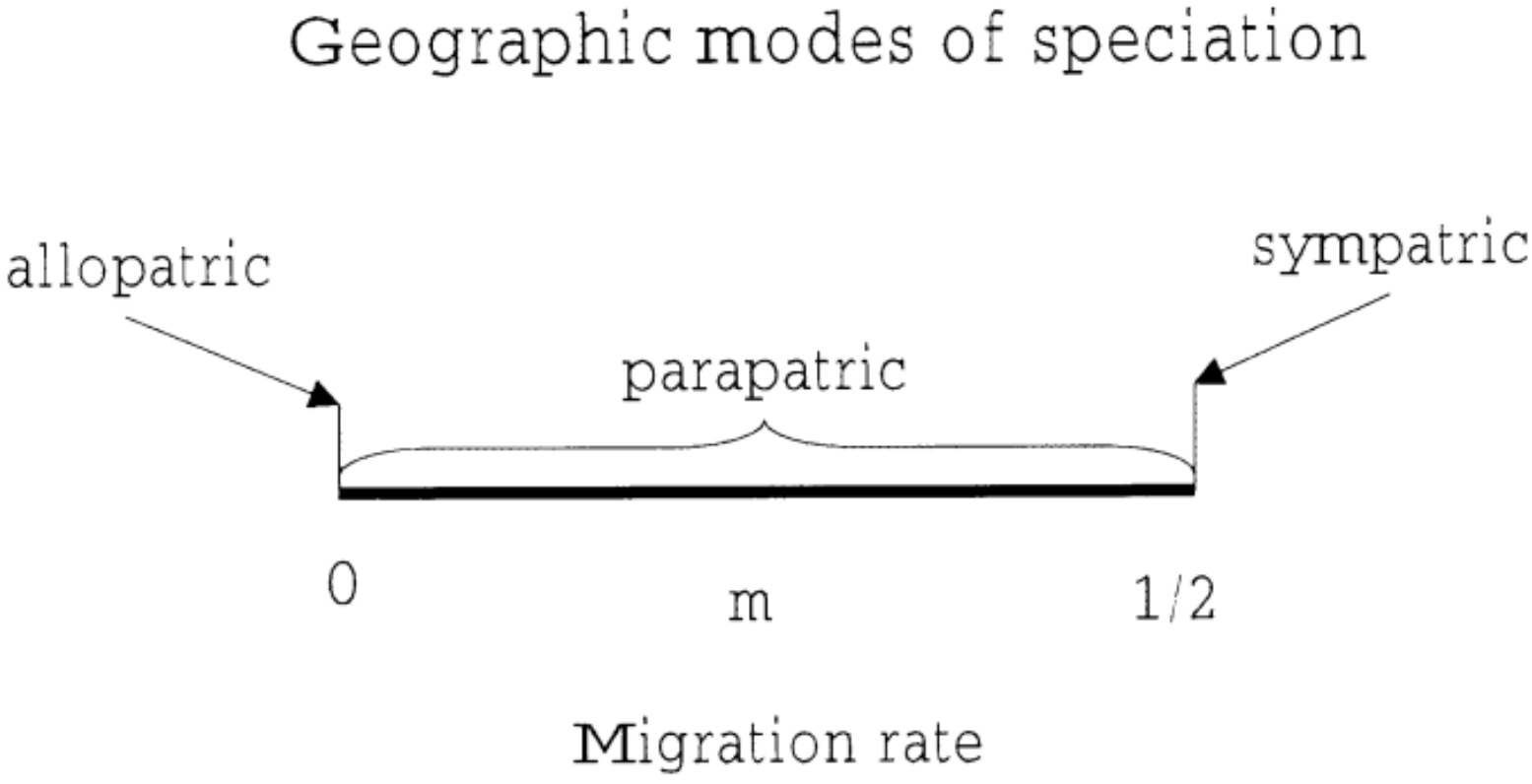


FIG. 1. Geographic modes of speciation.

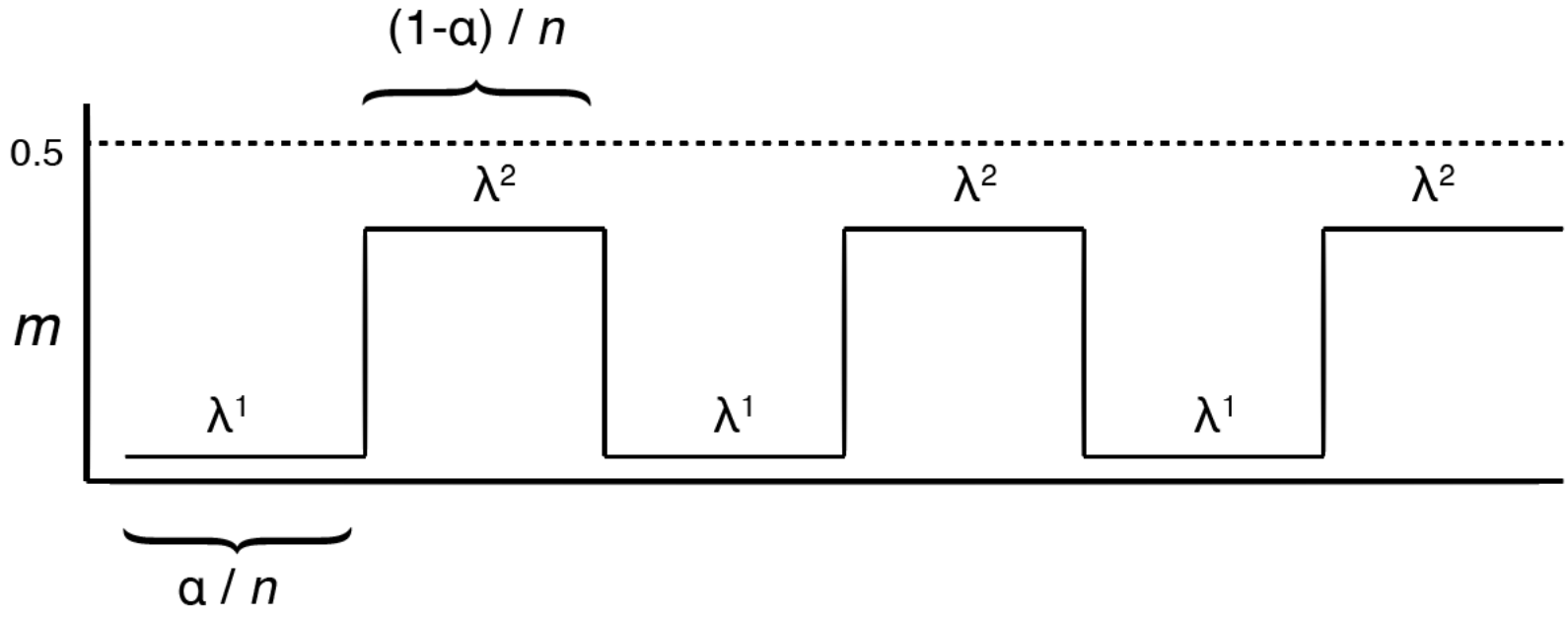
(Gavrilets 2003 *Evolution*)

For example: allopatric speciation

$$\overbrace{T^a}^{\text{time to speciation}} = \underbrace{2}_{\text{no. alleles}} * \overbrace{\frac{1}{\mu}}^{\text{substitution rate}} = \frac{2}{\mu}$$

H_1: Cyclical contact slows divergence, but not *that* much

Our own toy model

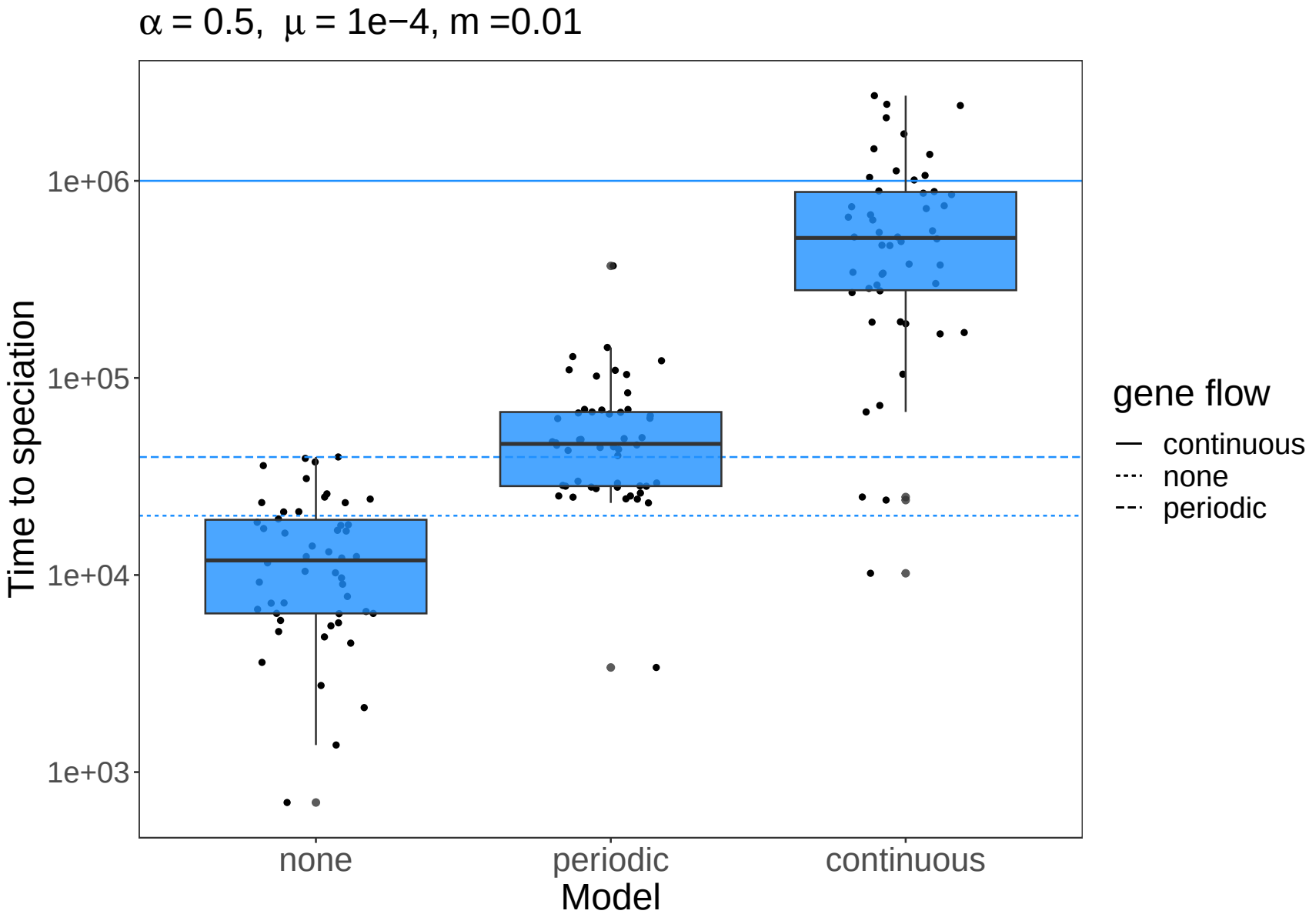


(Linck & Battey In revision *Am. Nat.*)

Our own toy model

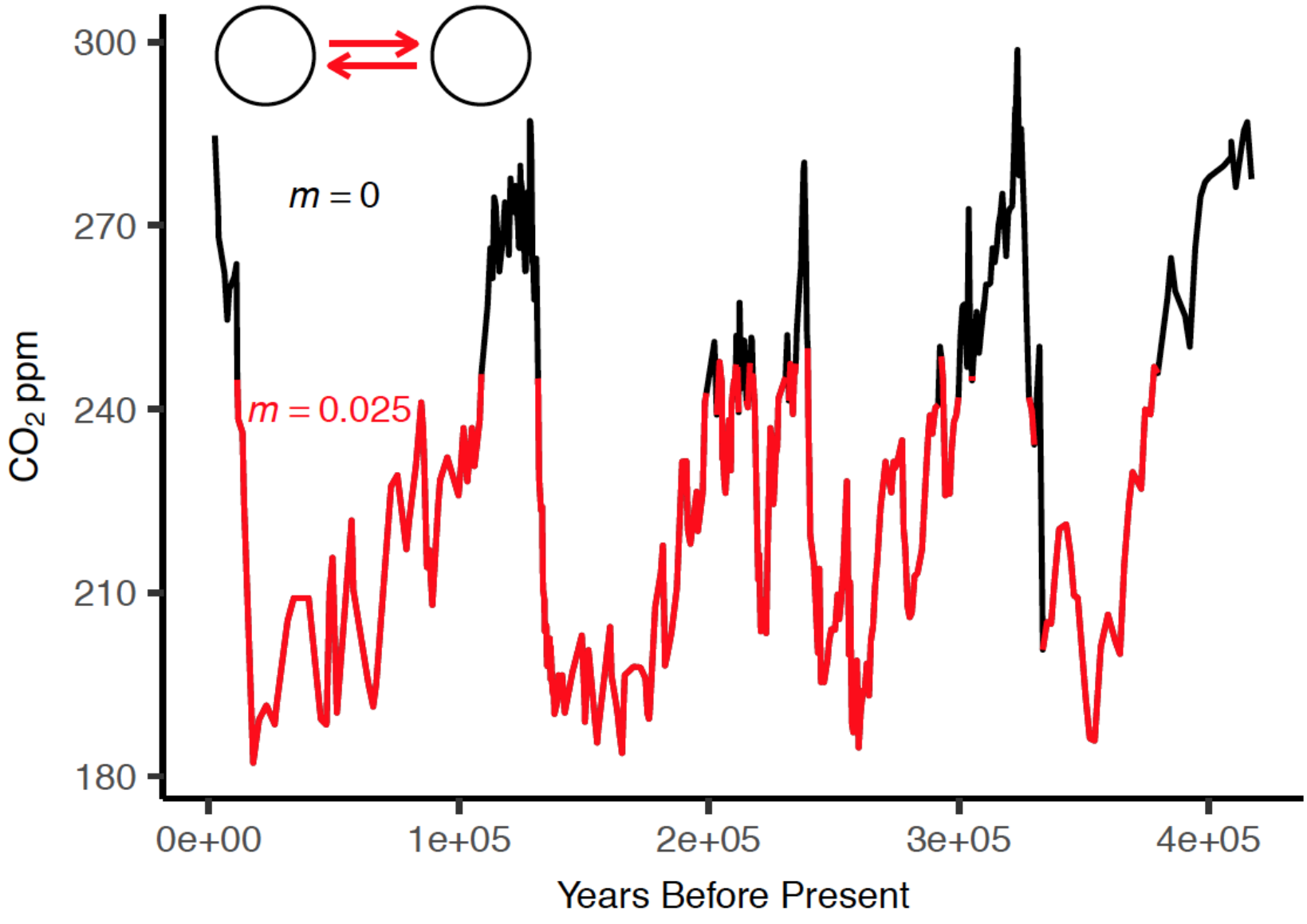
$$\overbrace{T^t}^{\text{time to speciation}} = \frac{\overbrace{n}^{\text{number of climate cycles}}}{\sum_{i=1}^{n} \underbrace{\alpha}_{\text{time in allo.}} \underbrace{\left(\frac{\mu}{2}\right)}_{\text{allo. model}} + \underbrace{(1-\alpha)}_{\text{time in para.}} \underbrace{\left(\frac{\mu^2}{m}\right)}_{\text{para. model}}}$$

Our own toy model

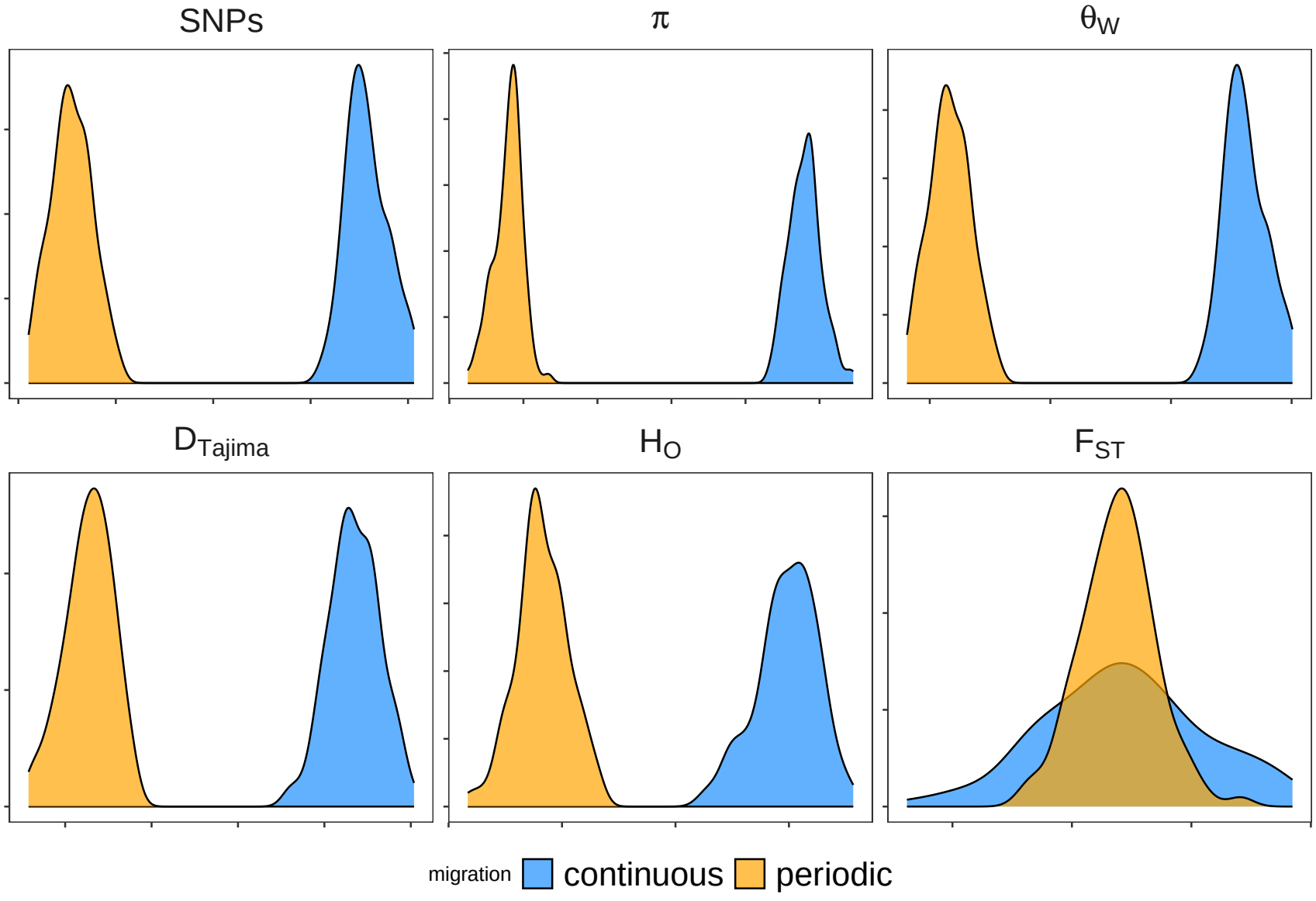


H_2: Cyclical contact has a distinct genomic signature

Parameterizing simulations



Different summary statistics



Takeaways

- Climate fidelity involved in an efficient mode of divergence
- Potentially detectable with sequence data
- Climatic complexity adds value to population genetic models
- **Application:** Identifying corridors of intermittent connectivity on the landscape

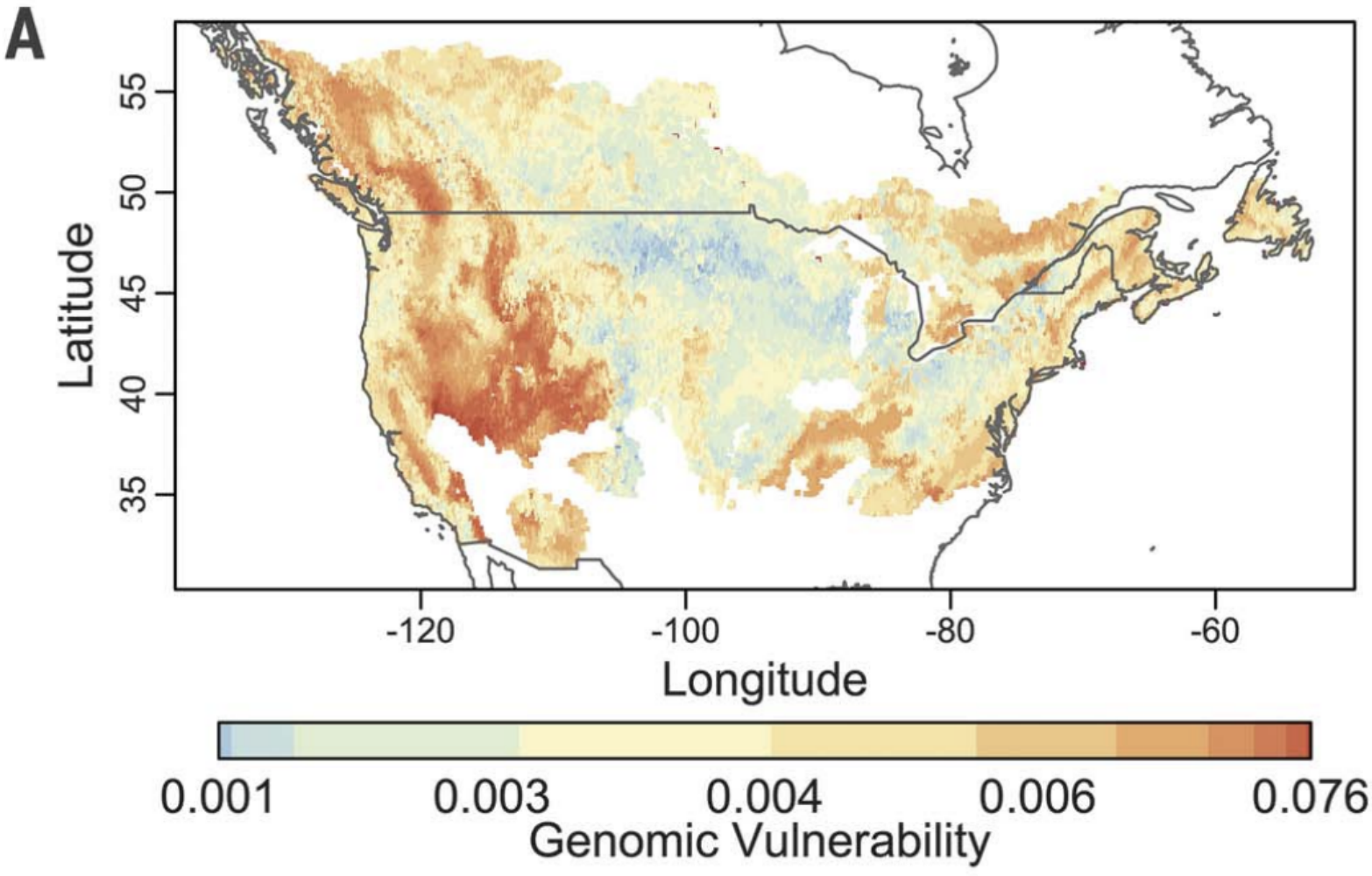
Outline

- Q_1: How has climate fidelity shaped genetic variation in Western *Empidonax* flycatchers?
- Q_2: What can we learn from adding climatic complexity to population genetic models?
- Q_3: **How can genomics help us predict vulnerability to climate change?**
- Q_4: What does any of this mean for conservation?

Acknowledgements:

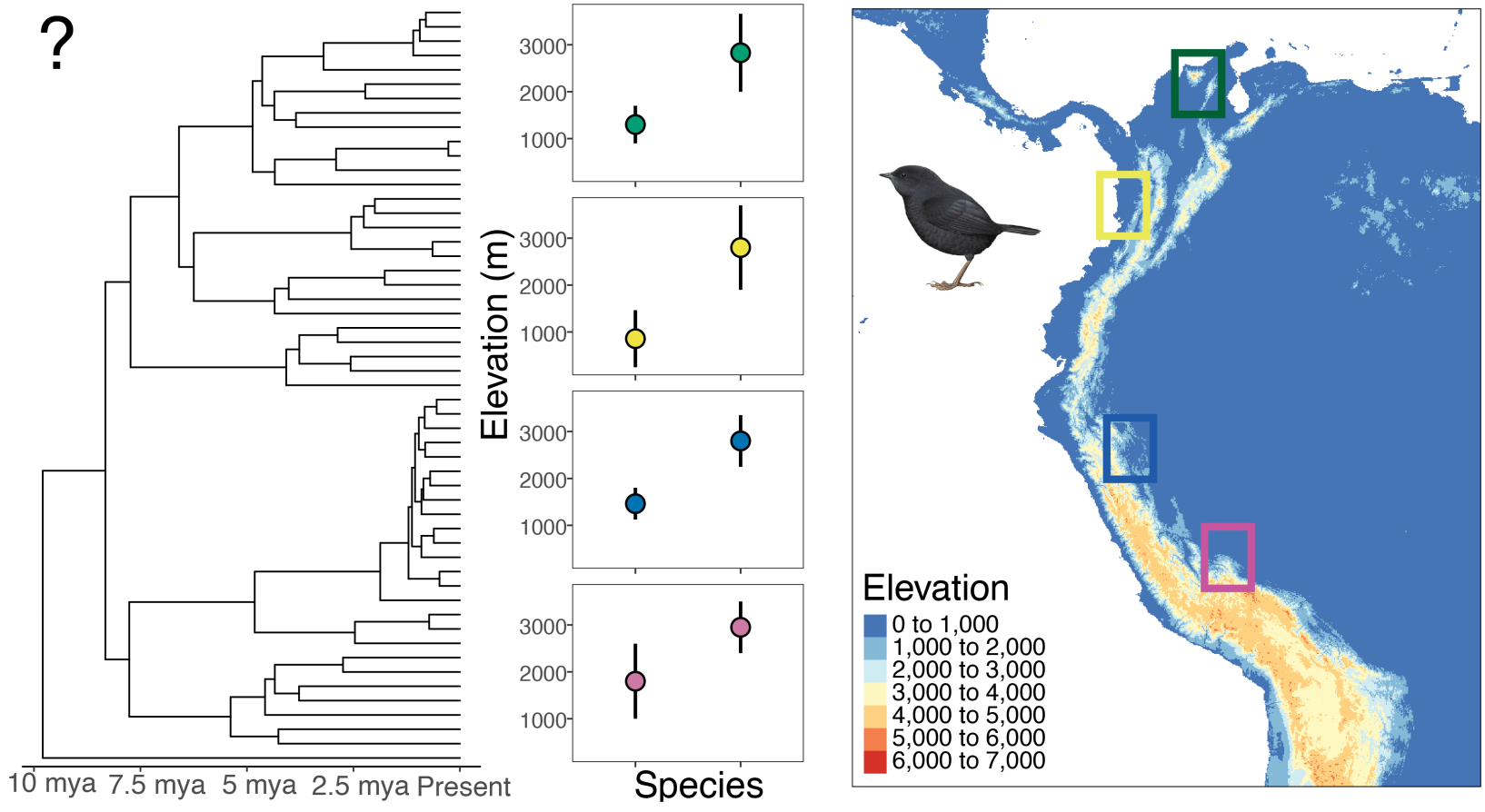
- **Collaborators**: Daniel Cadena, Cameron Ghalambor, Ben Freeman, Gavin Jones, Laura Céspedes
- **Funding**: NSF PRFB

Move, **adapt** / acclimate, or die



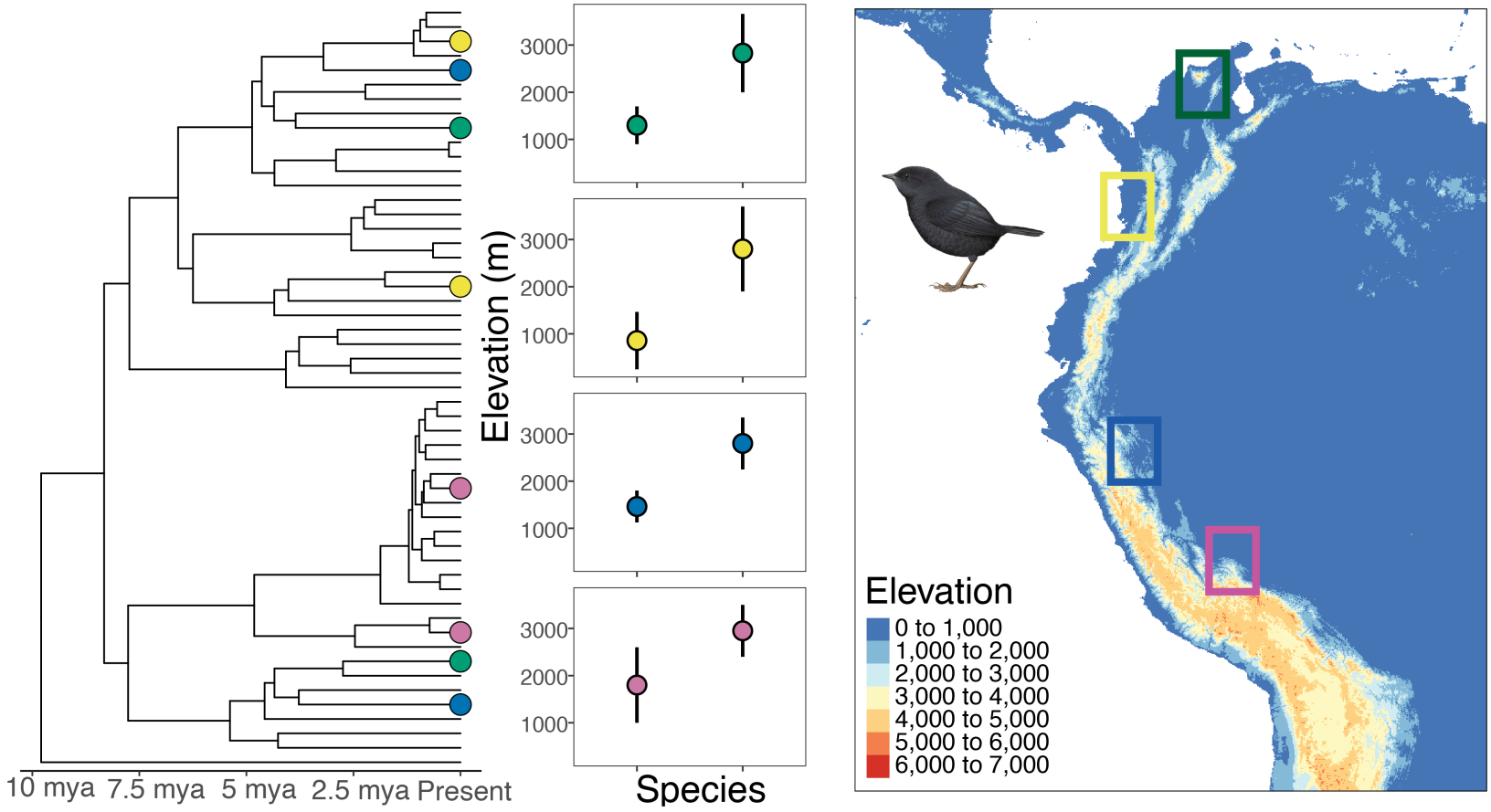
(Bay et al. 2018 *Science*)

How quickly do species adapt to new climates?



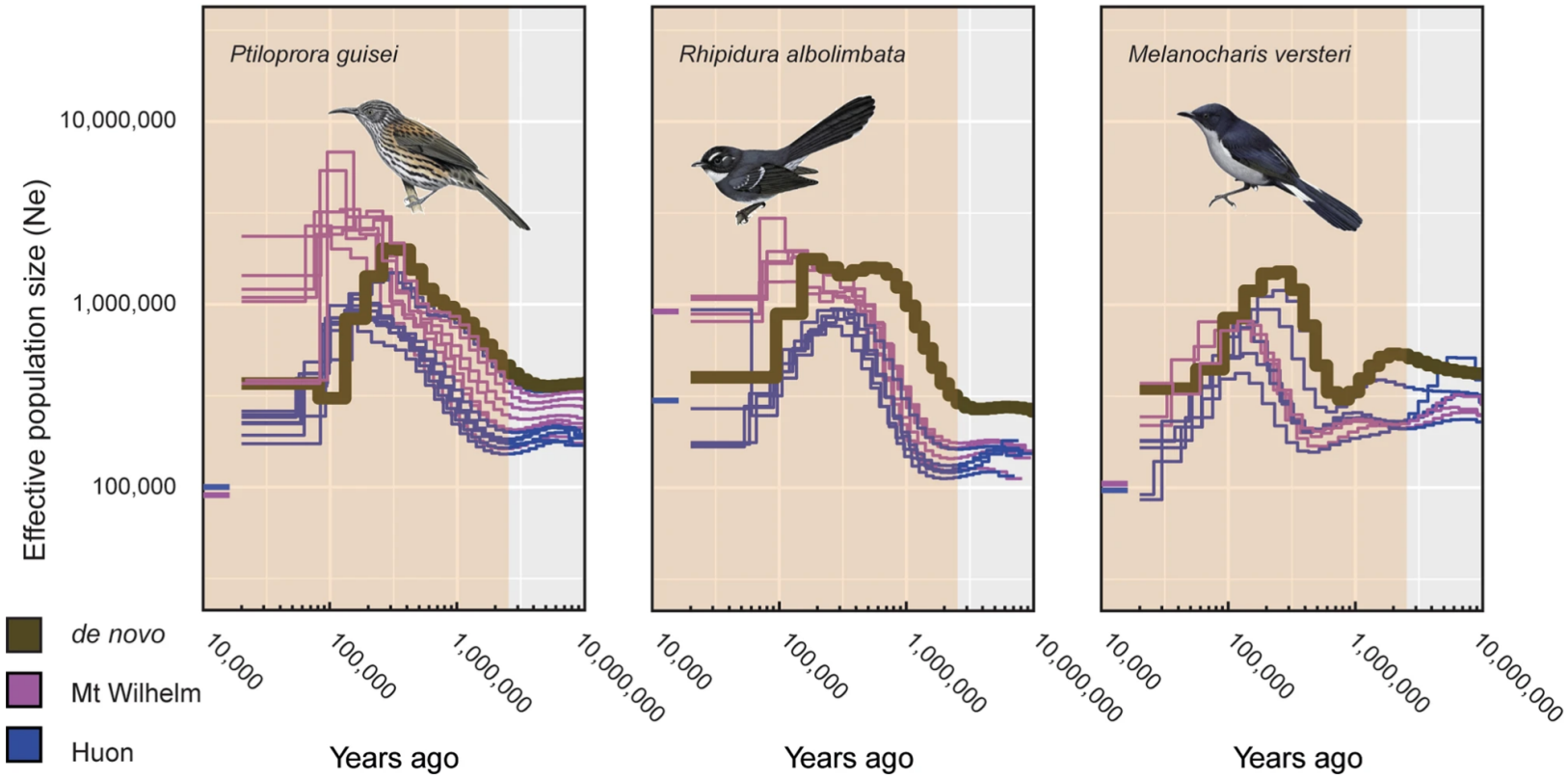
(Linck et al. 2021 *Biol. Lett.*)

Climate fidelity across phylogeny in tapaculos



(Linck et al. 2021 *Biol. Lett.*)

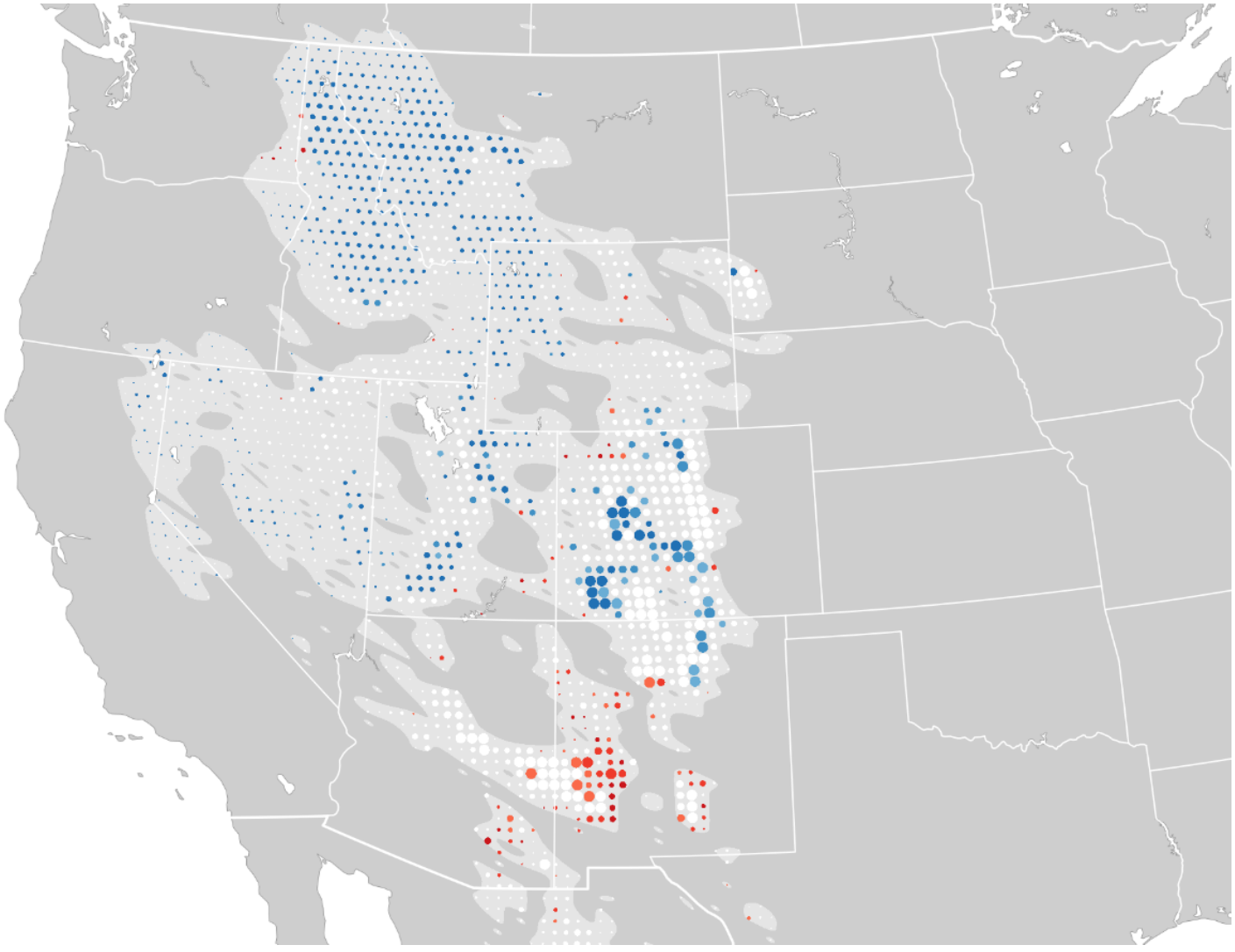
Climate fidelity shapes population trajectories



(Pujolar et al. 2022 *Nat. Comm.*)

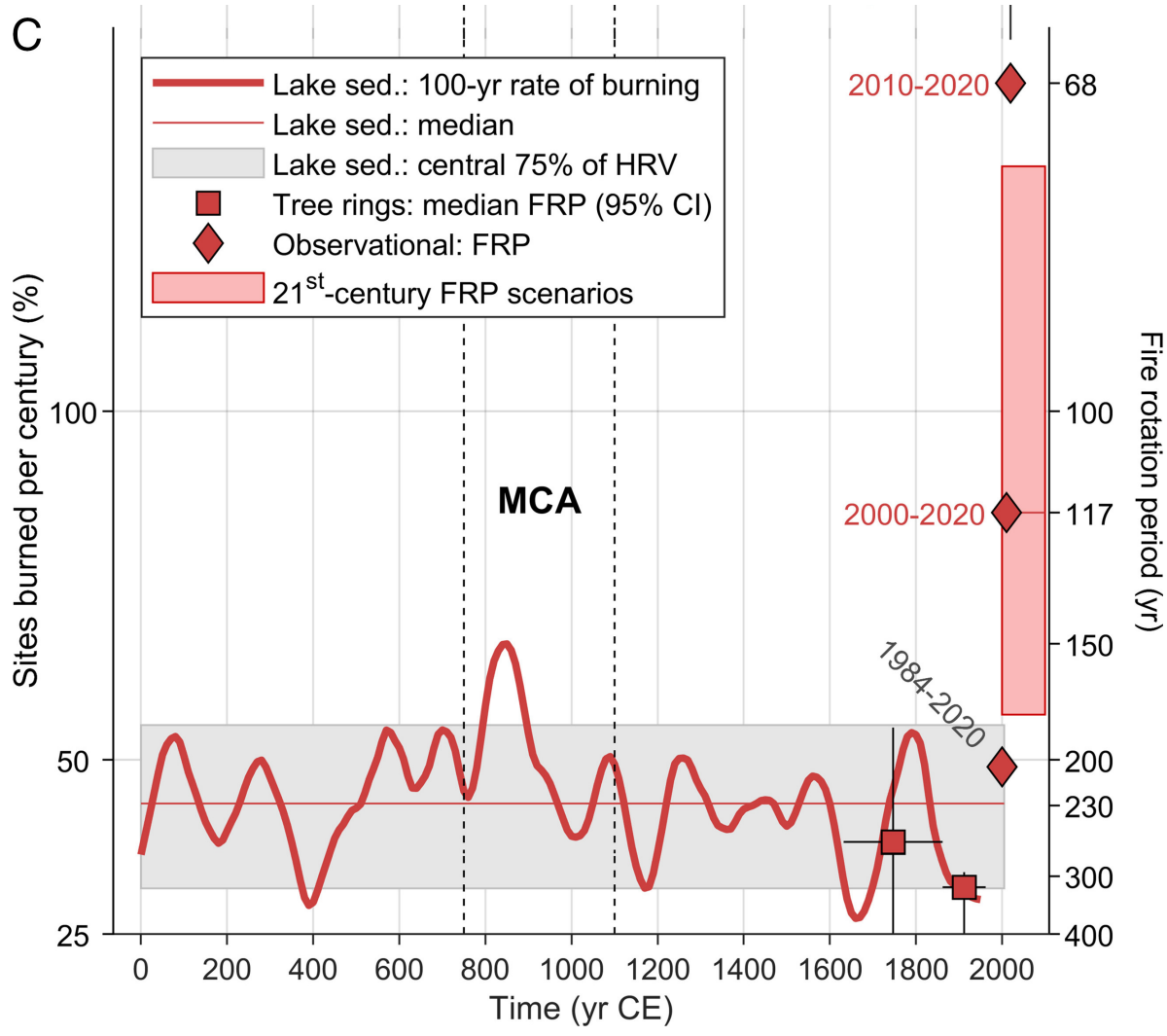
H_1: Climate fidelity tells us about adaptive potential to future climates

Western forests host niches under threat



(eBird)

Megafires as evolutionary experiment



(Higuera et al. 2021 *PNAS*)

Future work: Demographic responses to climate change in subalpine forest taxa

- Aim 1: What do we know about animal evolution in the "Pyrocene" (Jones et al. In review *TREE*)
- Aim 2: Did the Medieval Climate Anomaly leave a genomic signature in subalpine birds and mammals?
- Aim 3: Can museum genomics reveal population impacts of recent megafires?
- Aim 4: **Application:** Do metrics of climate fidelity improve assessments of risk?

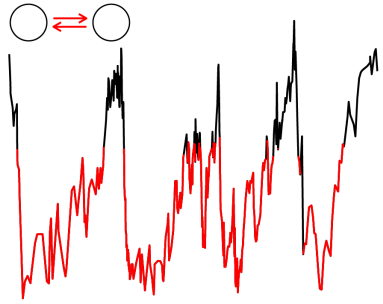
Takeaways

- Tapaculos adapt to new climates very slowly
- Climate fidelity shapes population trajectories
- Megafire is a natural experiment on genetic consequences of climate fidelity
- **Application:** The genomic signature of climate fidelity contains information for risk metrics and prioritization

Outline

- Q_1: How has climate fidelity shaped genetic variation in Western *Empidonax* flycatchers?
- Q_2: What can we learn from adding complexity to population genetic models?
- Q_3: How can genomics help us predict vulnerability to climate change?
- Q_4**: What does any of this mean for conservation?**

Conservation connects data to policy levers



species / ESUs → ESA

historical connectivity → global priority mapping → land conservation

risk metrics → prioritization → intervention

Conservation is mostly about people

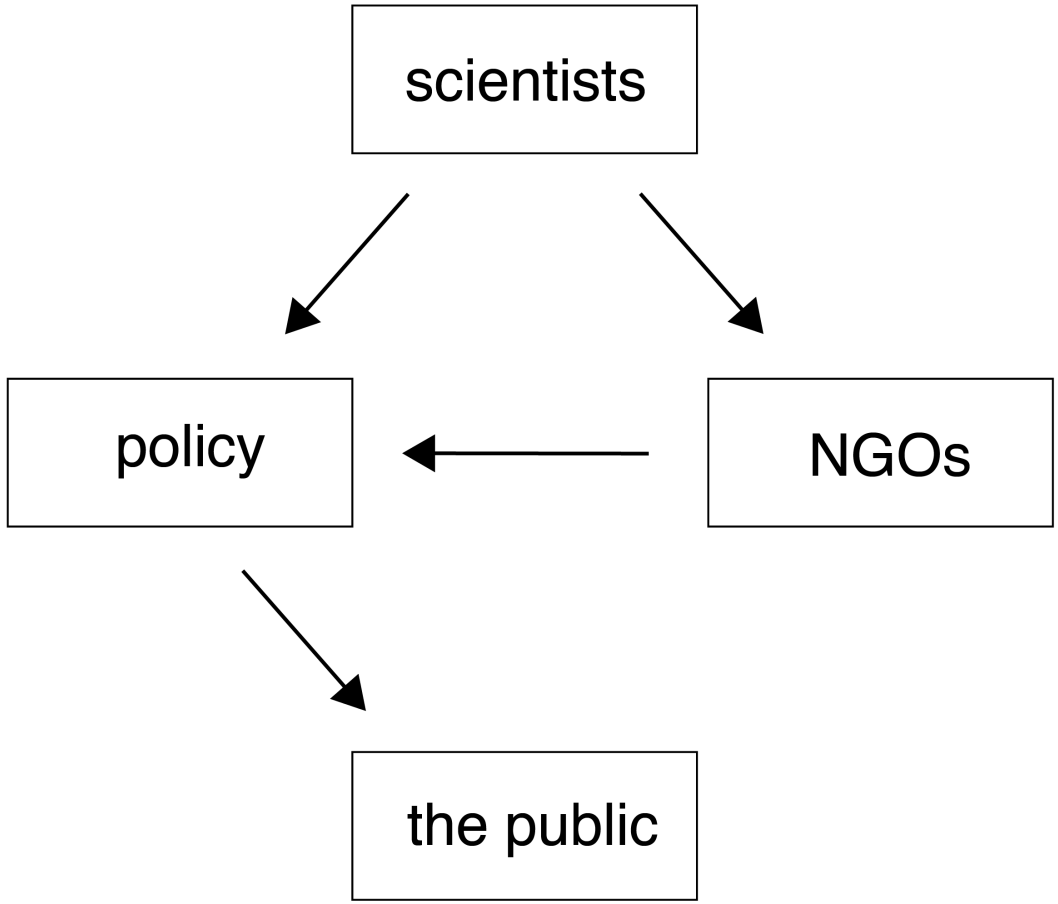
(Schimel & Linck 2019 *bioGraphic*)

Values influence the interpretation of data

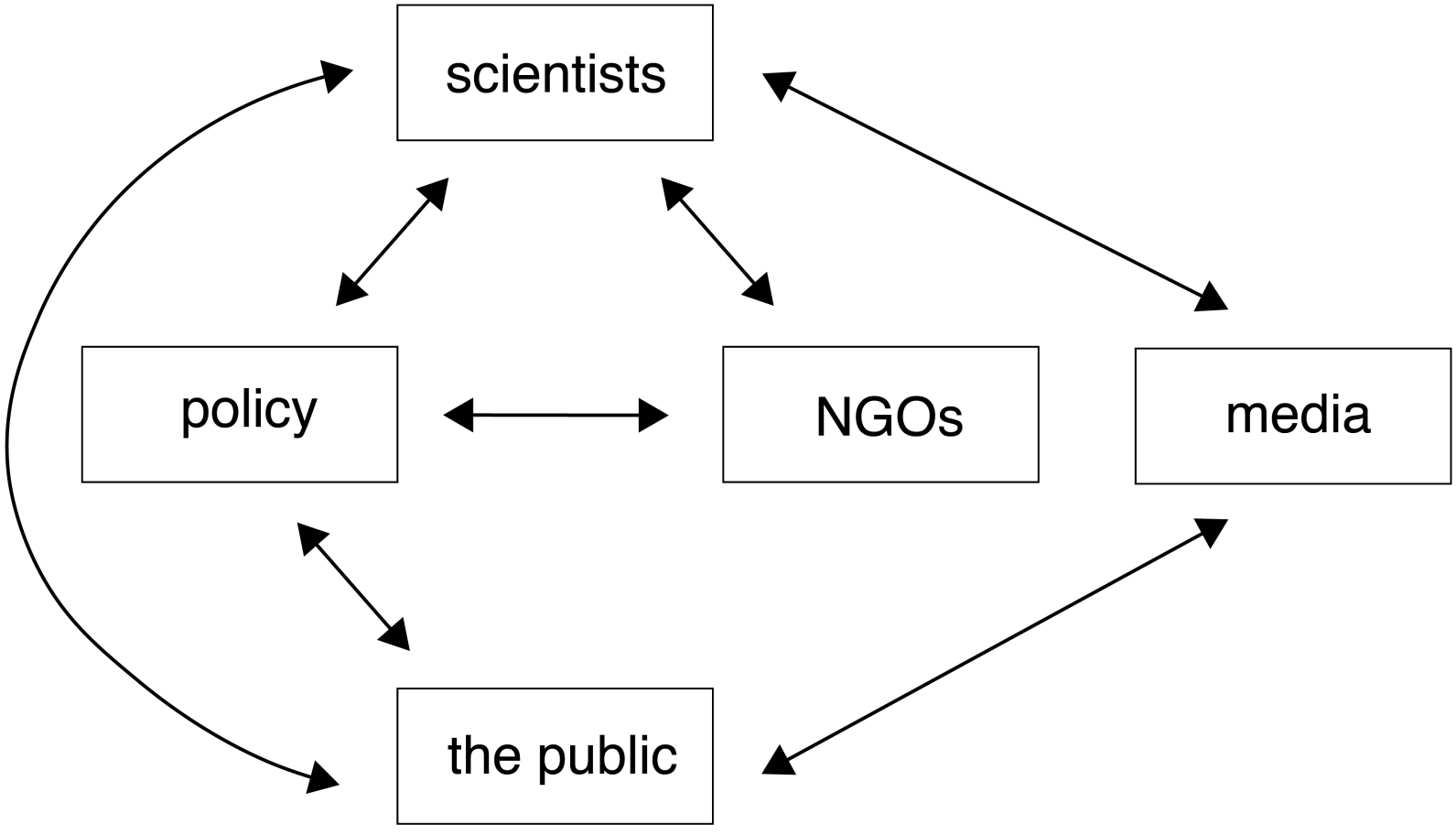
"They have wolves on the Gaza Strip. They have wolves in Italy. They have wolves in Northern-freaking-California. Why can't we have wolves here?"

(Rob Edwards of RMWP in Linck 2020, *High Country News*)

Conservation as a chain



Conservation as a network



Resources

- slides and code: https://github.com/elinck/misc_talks/
- website: https://elinck.org/
- twitter: @ethanblinck

References

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- Schimel & Linck 2020. *bioGraphic*.
- Linck 2020. *High Country News*.

Thanks!

- Q_1: Climate fidelity and montane geography explain genetic structure in *Empidonax* flycatchers
- Q_2: Climatic complexity adds value to population genetic models
- Q_3: The genomic signature of past climate fidelity may contain information about future risk
- Q_4: Conservation is a network, not a chain