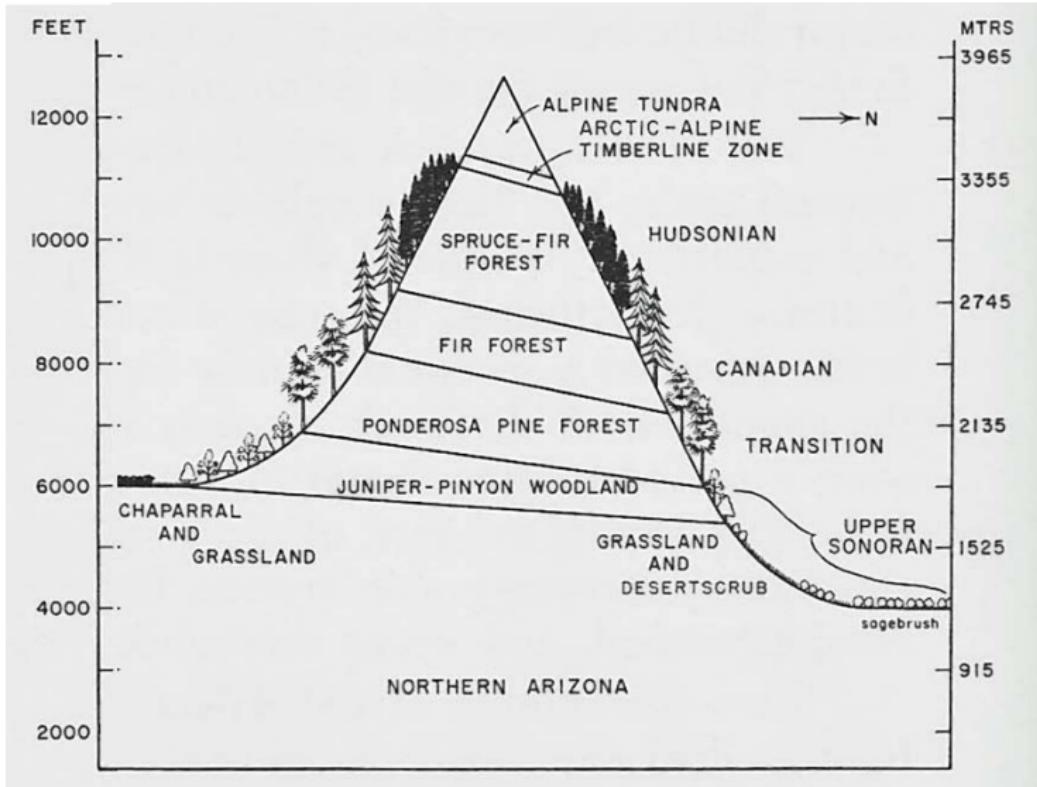


Climate fidelity, genetic variation, and evolutionary potential

Ethan B. Linck

University of Wyoming
Department of Zoology & Physiology
@ethanblinck

Climate structures biodiversity



(Merriam 1890)

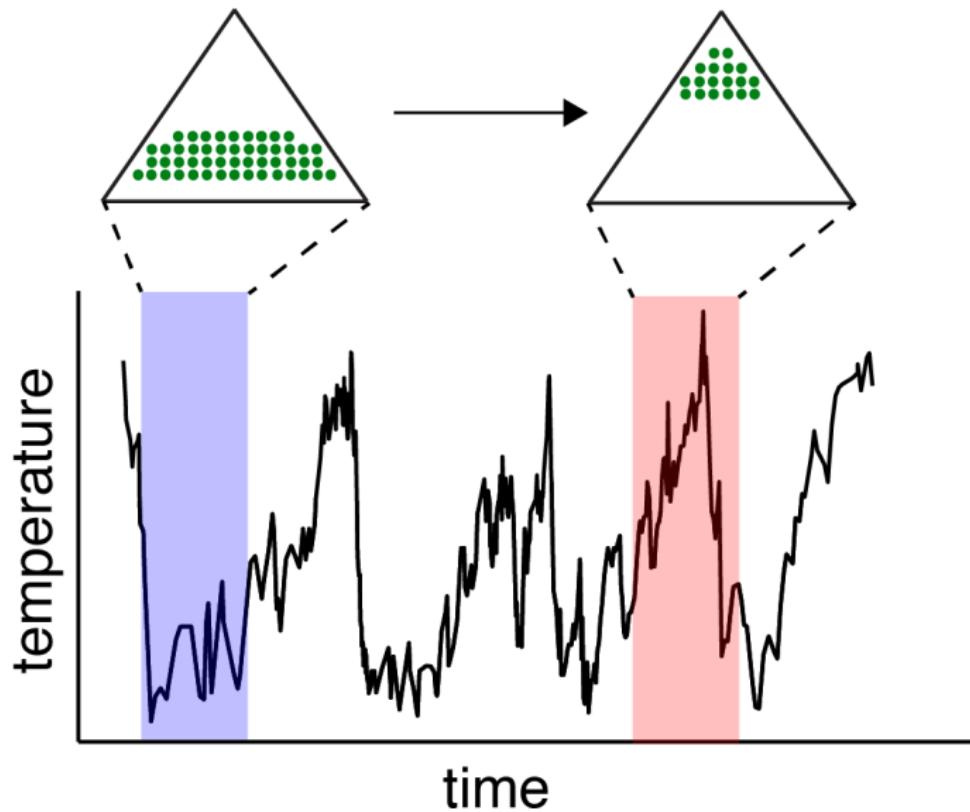
Climate structures biodiversity



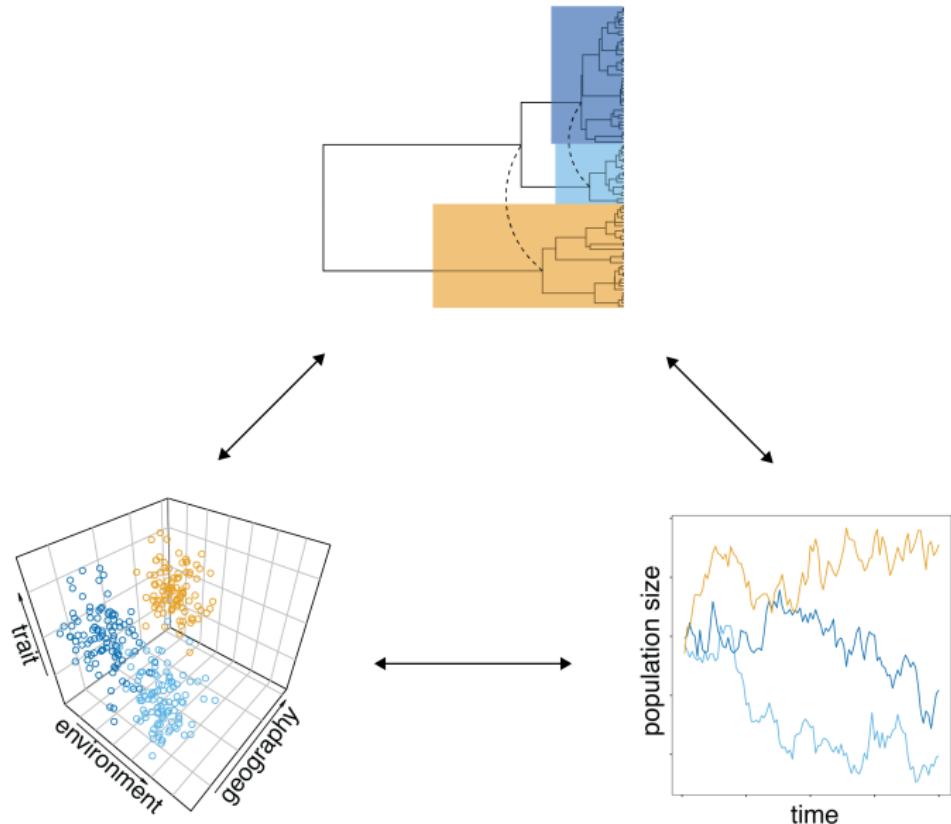
(iNaturalist obs. 128348716, 30912579, 31832514, 33570367)

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

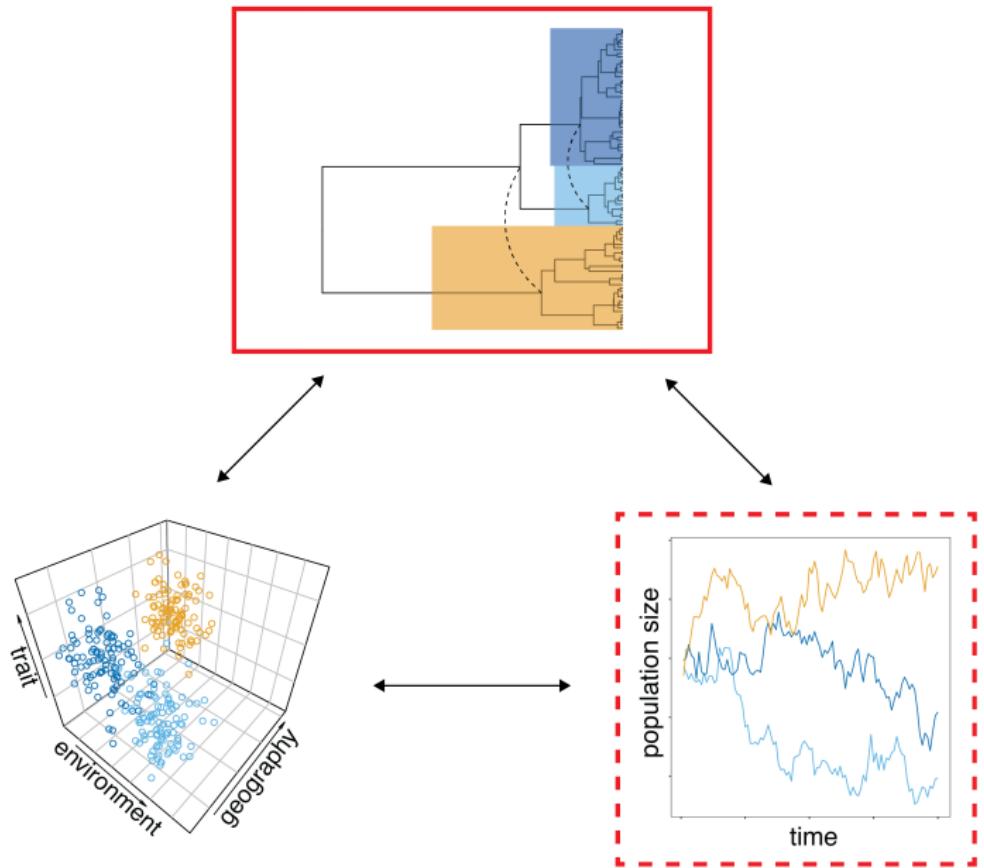
Climate fidelity



Integrative population genetics



Integrative population genetics



How does climate fidelity structure
genetic variation, and why do we care?

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 : What can climate fidelity tell us about evolutionary potential?
- ▶ Q_4 : What is the role of evolutionary thinking in conservation biology?

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 : What can climate fidelity tell us about evolutionary potential?
- ▶ Q_4 : What is the role of evolutionary thinking in conservation biology?

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

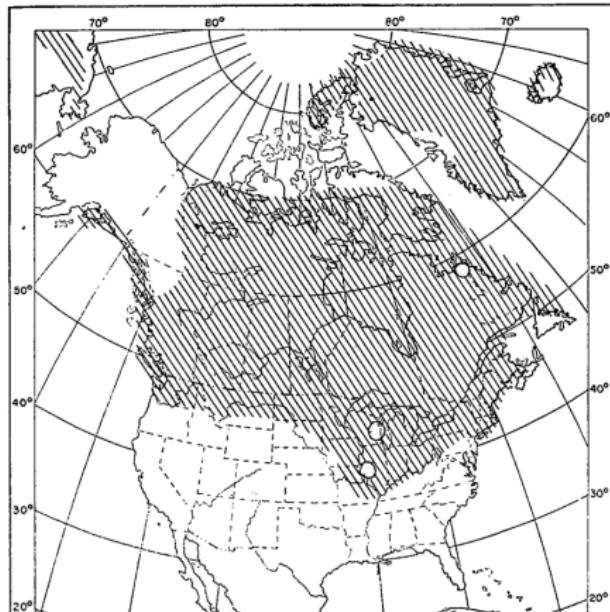
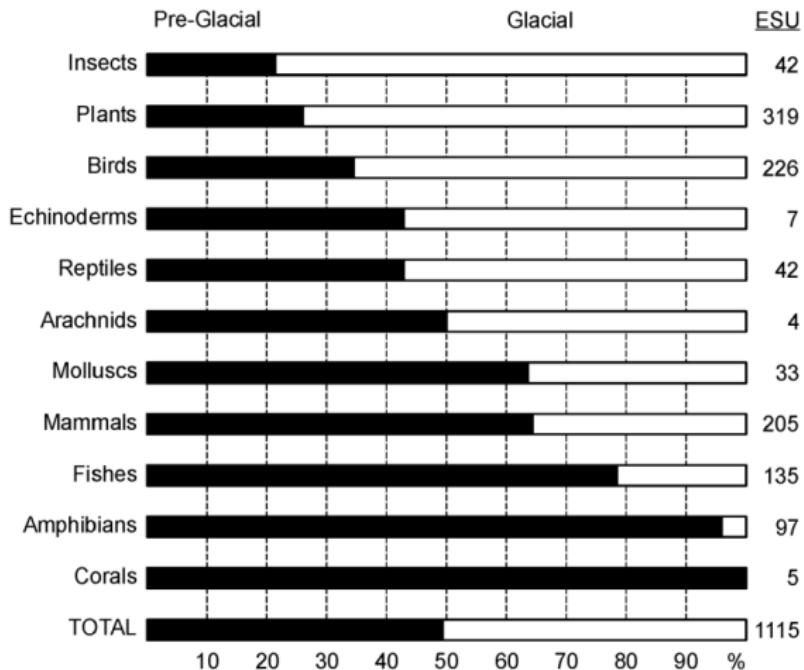


FIG. 1. Maximum extent of solid ice sheets according to Hulten, 1937; additional local glaciation also occurred. Flint (see fig. 2) believes that glaciation was more extensive than this.

(Rand 1948 *Evolution*)

Climatic cycles shape biodiversity



(Rull 2008 *Molecular Ecology*)

“Western” *Empidonax* Flycatchers



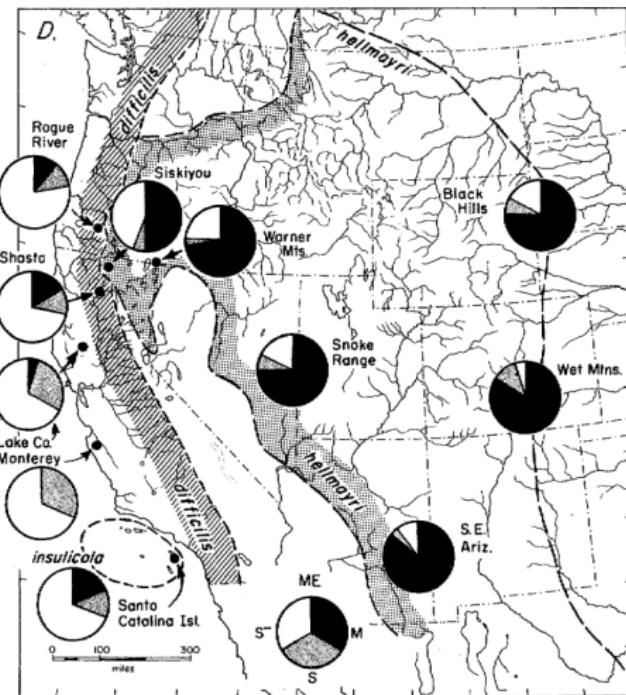
Cordilleran Flycatcher (COFL)
Empidonax occidentalis



Pacific-slope Flycatcher (PSFL)
Empidonax difficilis

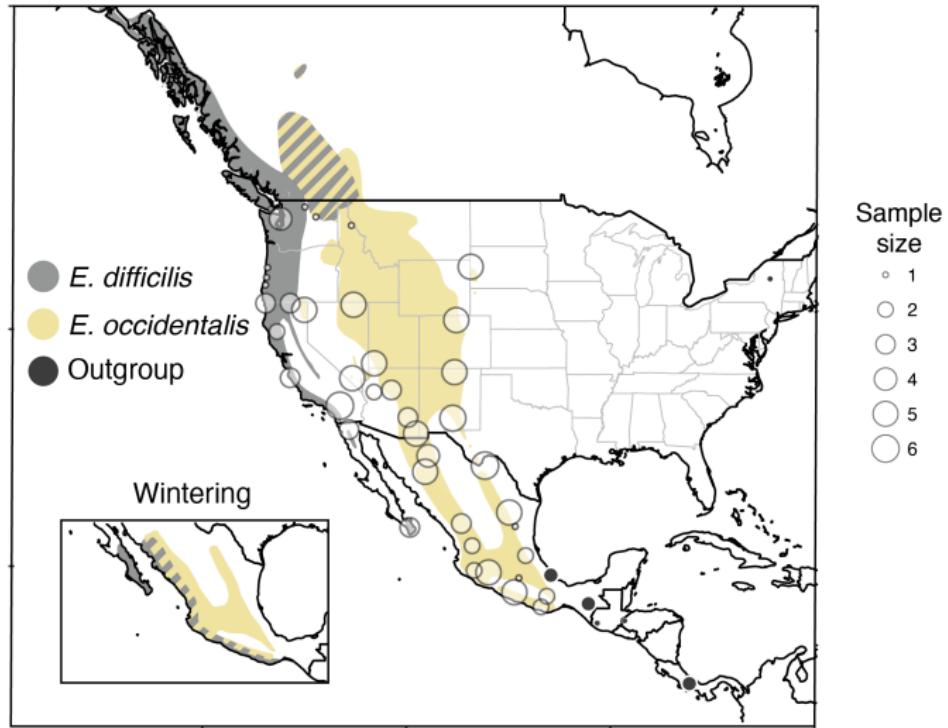
(Macaulay Library 109315481 & 236799211)

One species or two?



(Johnson & Marten 1988 *Auk*)

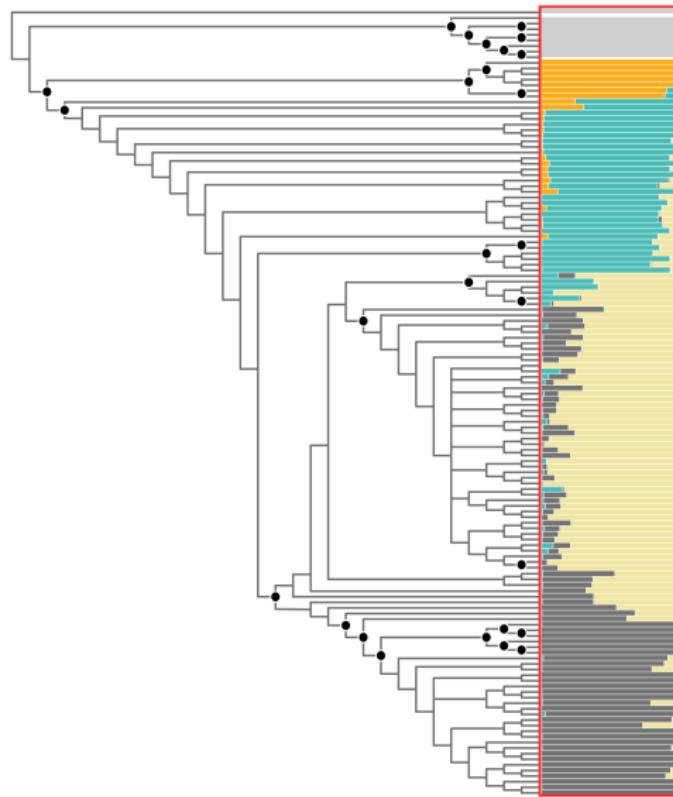
New information, more genes, more geography



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

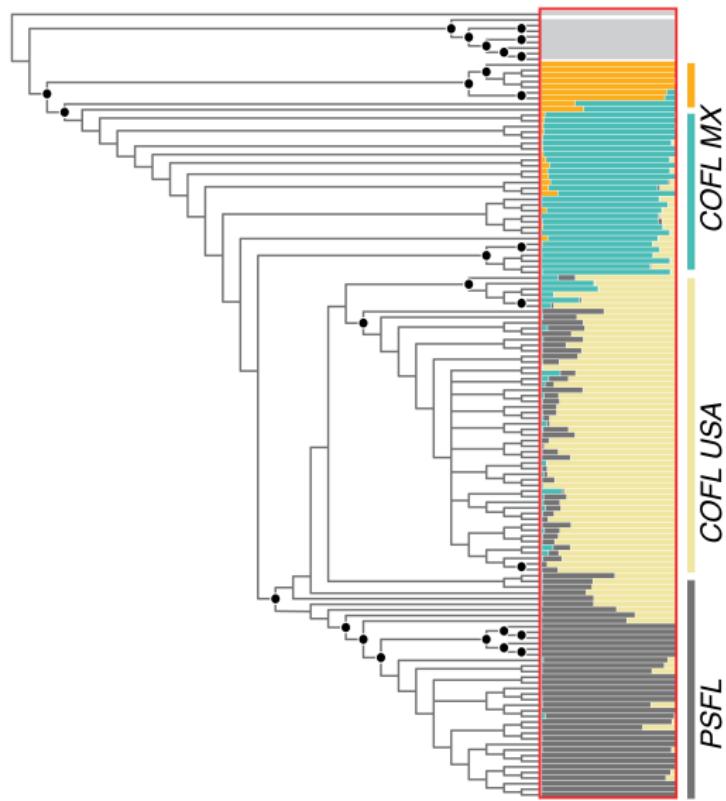
H_1 : Mountain ranges structure genetic variation in Western *Empidonax*

Geographically structured populations



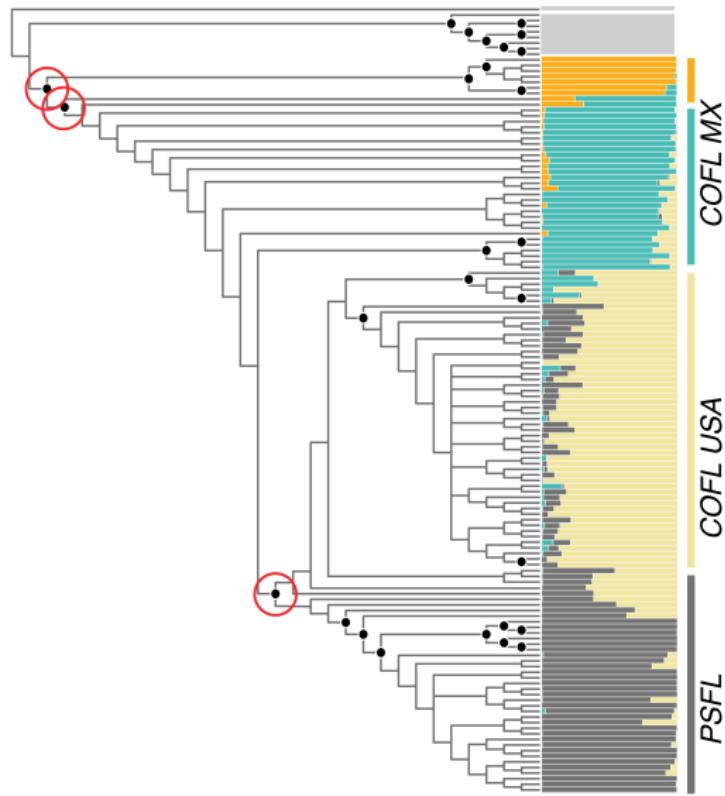
(Linck et al. 2019 *Syst. Biol.*)

Geographically structured populations



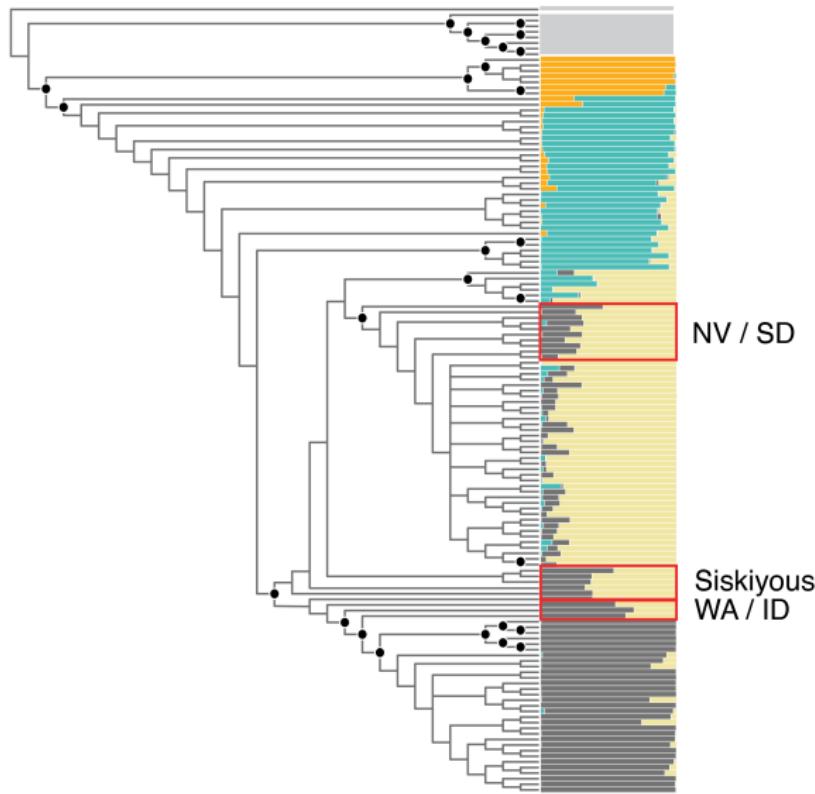
(Linck et al. 2019 *Syst. Biol.*)

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
- ▶ There's no getting around comprehensive sampling for delimitation of management units
- ▶ Climate fidelity and montane geography explain genetic structure in *Empidonax* flycatchers

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 : What can climate fidelity tell us about evolutionary potential?
- ▶ Q_4 : What is the role of evolutionary thinking in conservation biology?

Acknowledgements:

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

Climatic cycles shape biodiversity

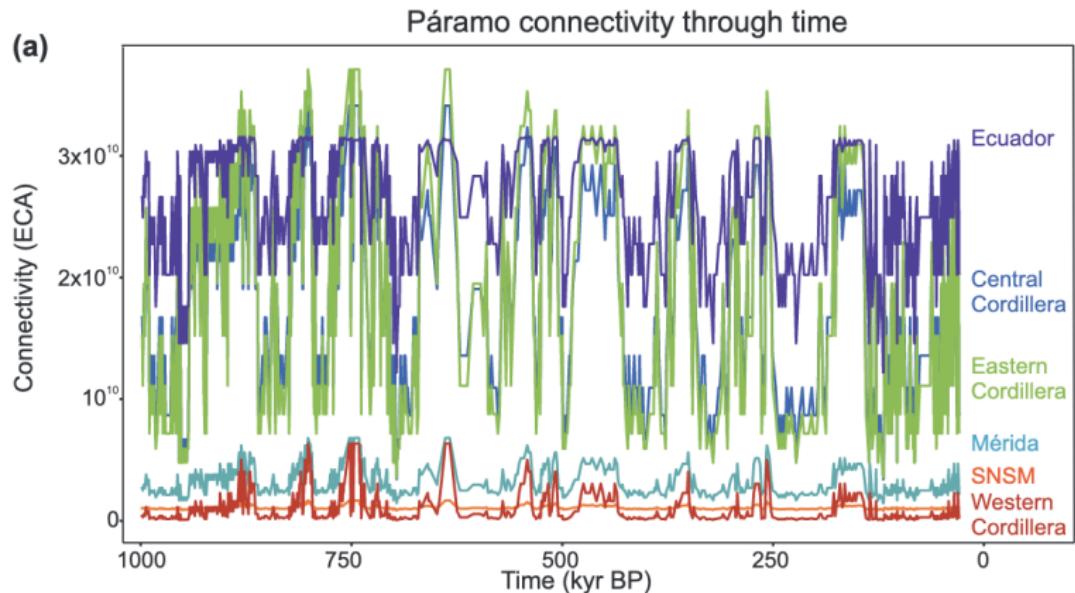
GLACIATION, A FACTOR IN SPECIATION



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

Geographic modes of speciation

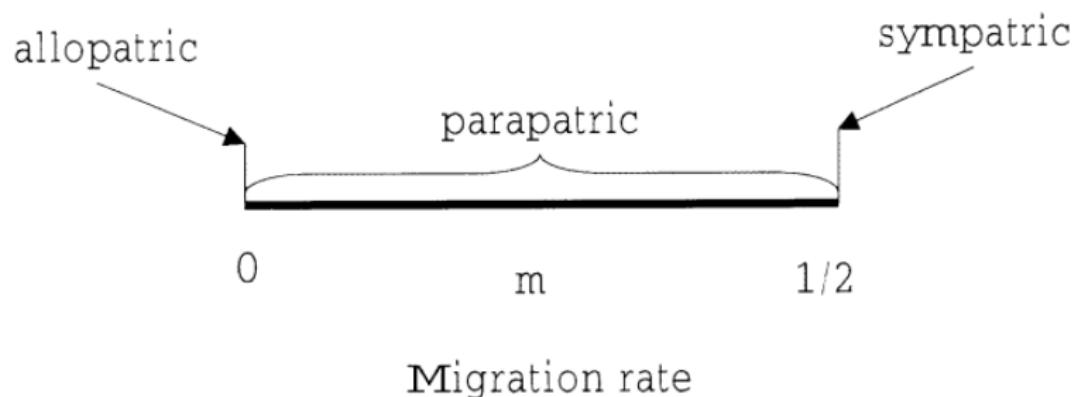


FIG. 1. Geographic modes of speciation.

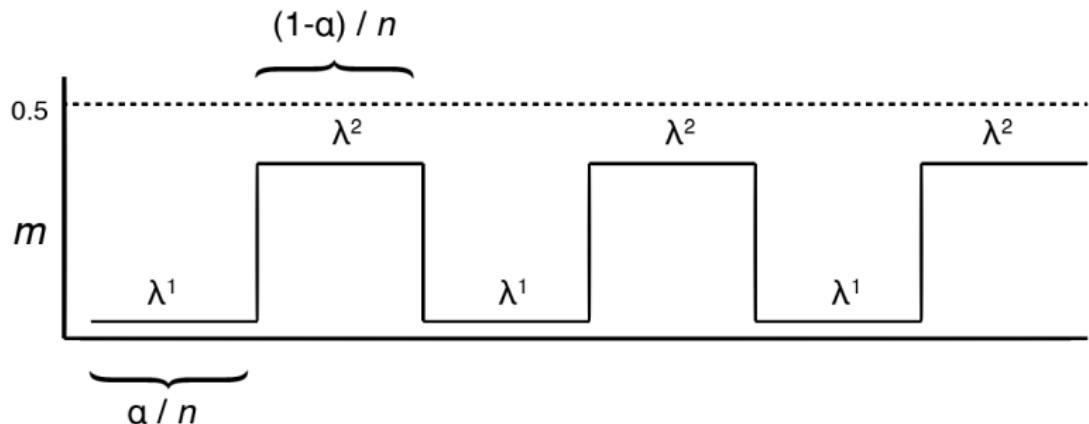
(Gavrilets 2003 *Evolution*)

For example: allopatric speciation

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

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

Our own toy model



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

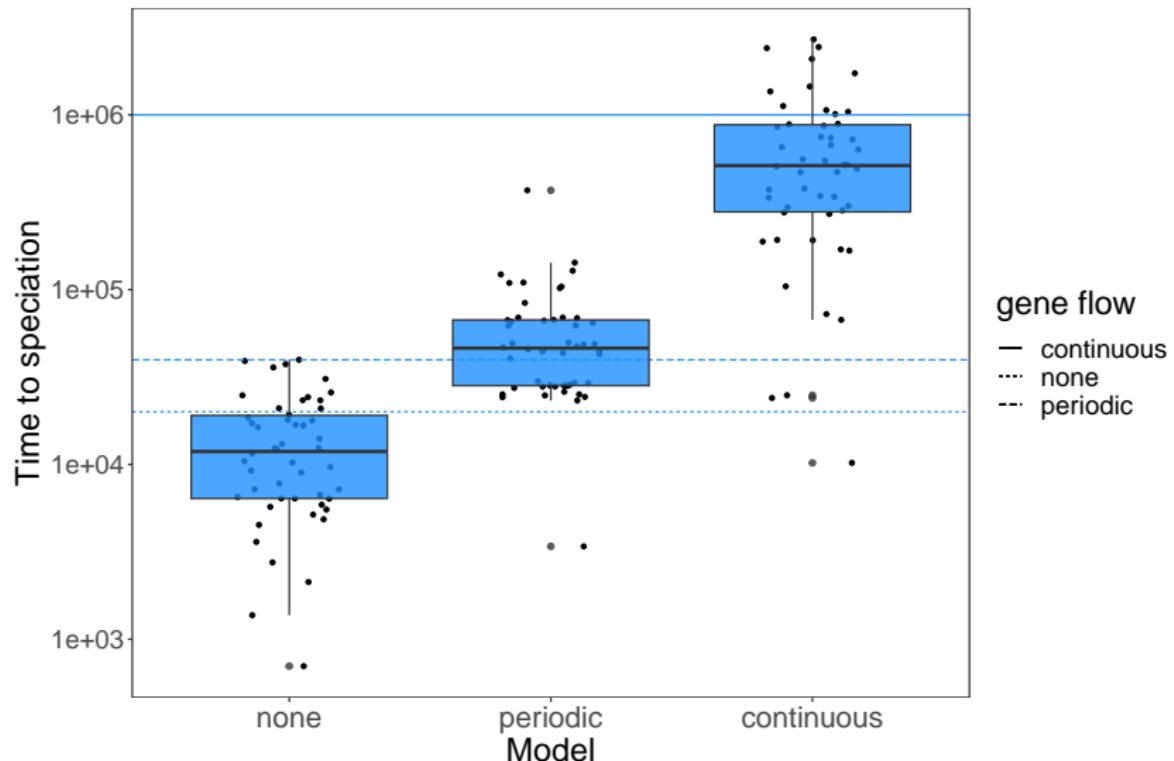
Our own toy model

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

number of climate cycles
 \widehat{n}

Our own toy model

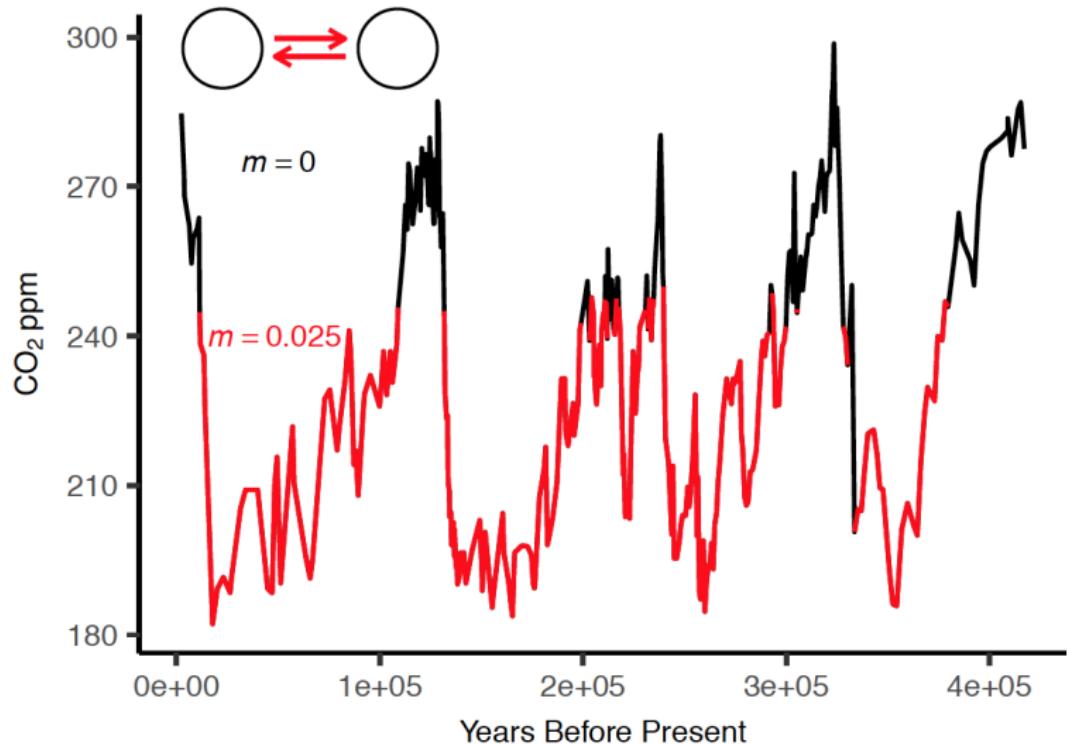
$\alpha = 0.5$, $\mu = 1e-4$, $m = 0.01$



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

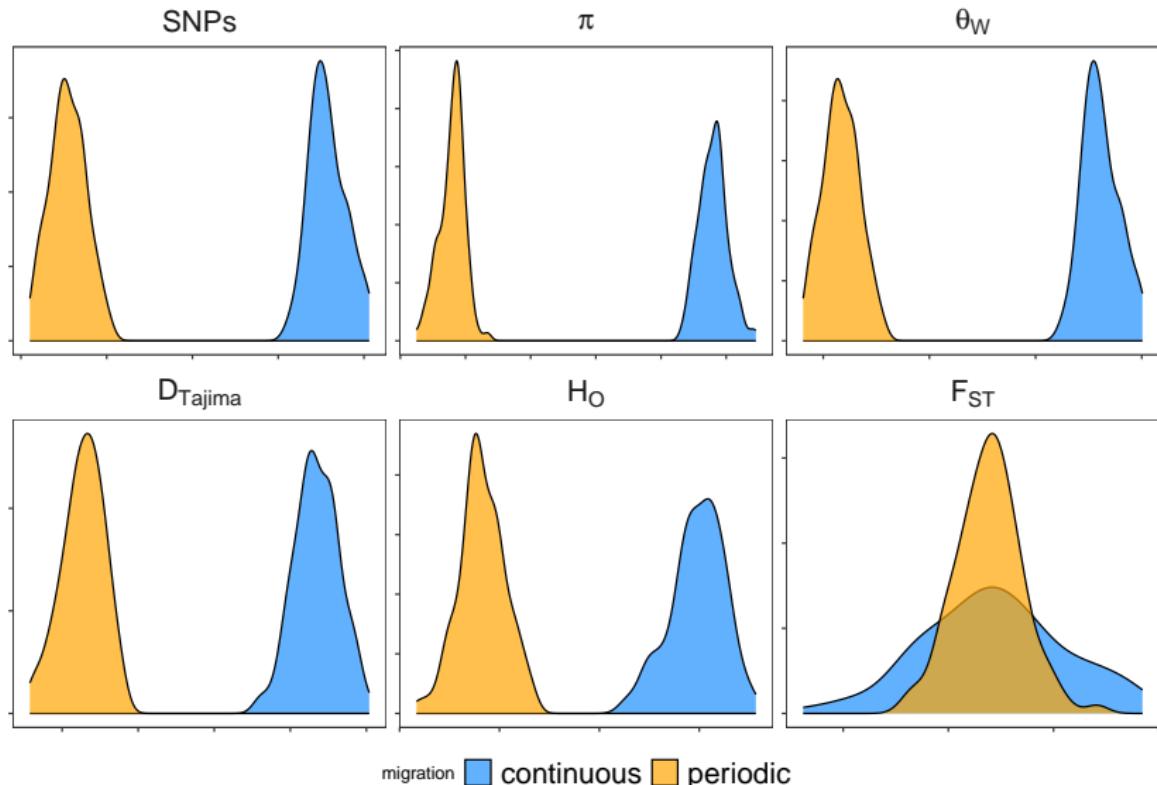
H_2 : Cyclical contact has a distinct genomic signature

Parameterizing simulations



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

Different summary statistics



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

Takeaways

- ▶ Climate fidelity involved in an efficient mode of divergence
- ▶ The timing of gene flow matters
- ▶ Potentially detectable with sequence data
- ▶ Climatic complexity adds value to population genetic models

Outline

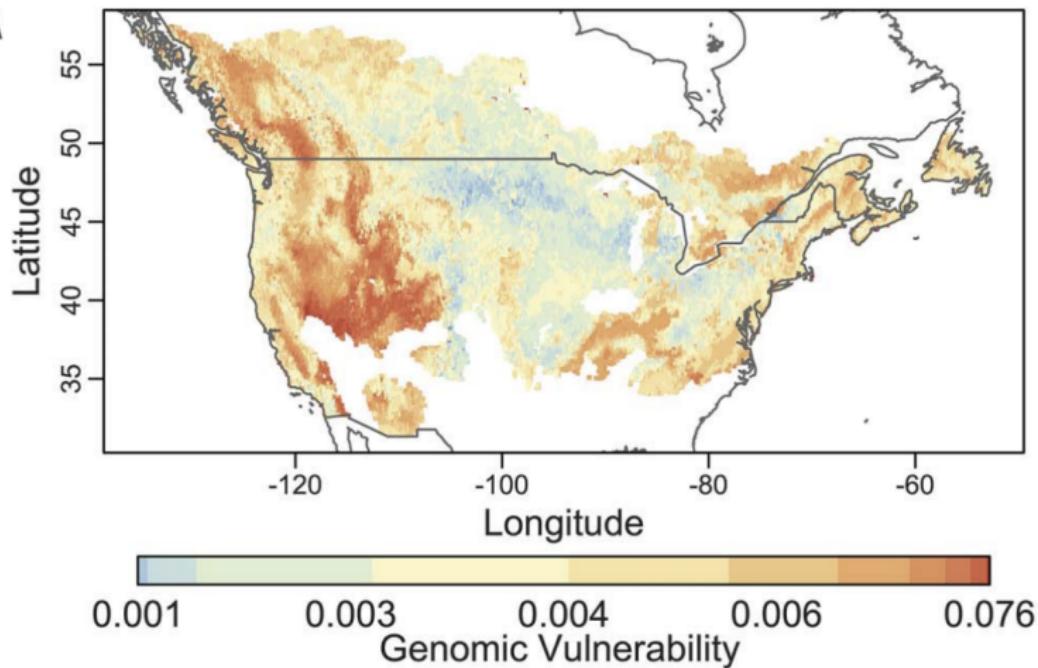
- ▶ Q_1 : How has climate fidelity shaped genetic variation in Western *Empidonax* flycatchers?
- ▶ Q_2 : What can we learn from adding climatic complexity to population genetic models?
- ▶ **Q_3 : What can climate fidelity tell us about evolutionary potential?**
- ▶ Q_4 : What is the role of evolutionary thinking in conservation biology?

Acknowledgements:

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

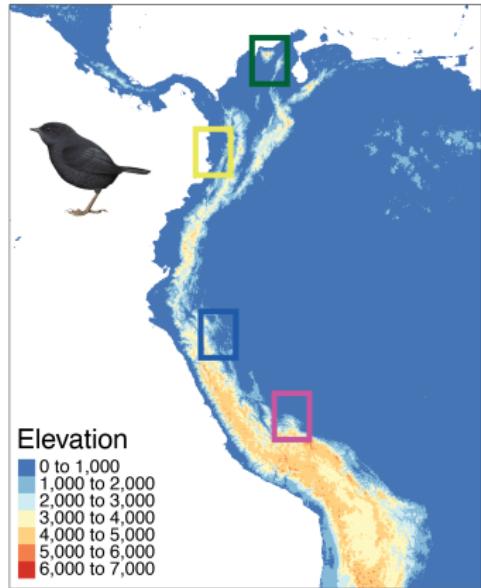
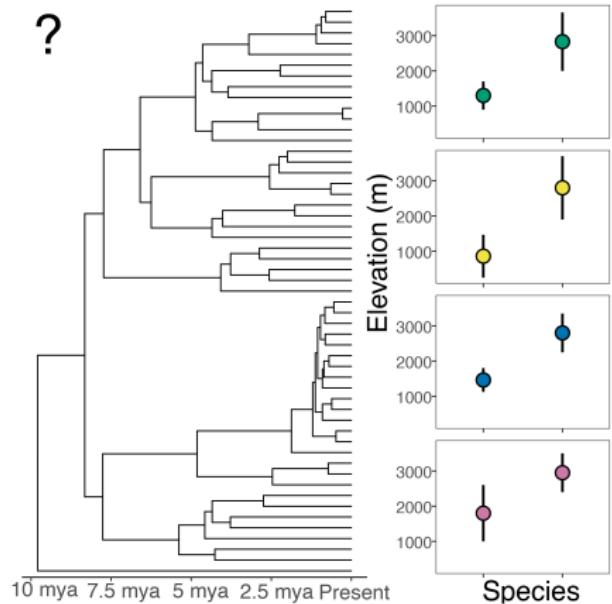
Move, **adapt** / acclimate, or die

A



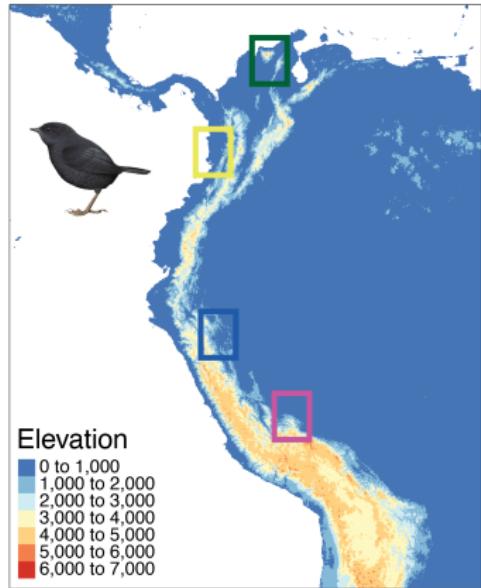
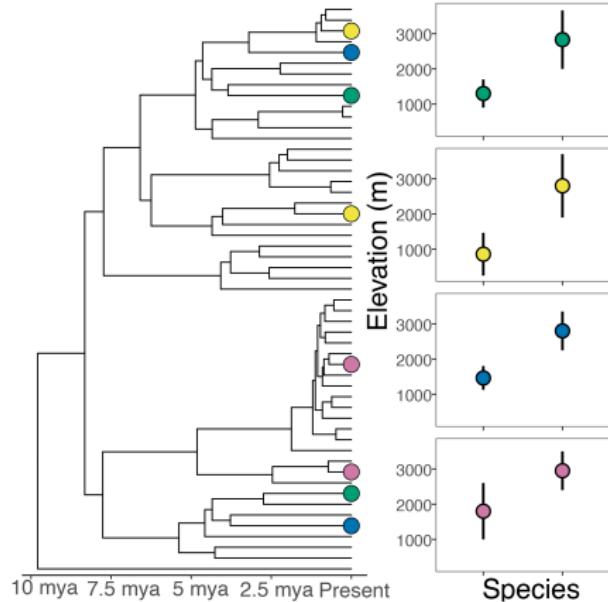
(Bay et al. 2018 *Science*)

How quickly do species adapt to new climates?



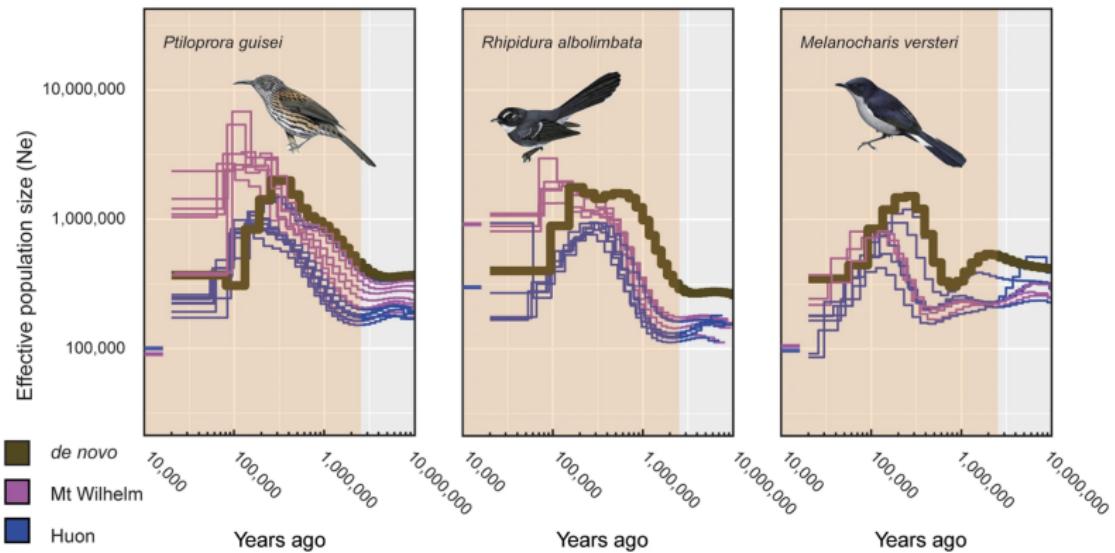
(Linck et al. 2021 *Biol. Lett.*)

Climate fidelity across phylogeny in tapaculos



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

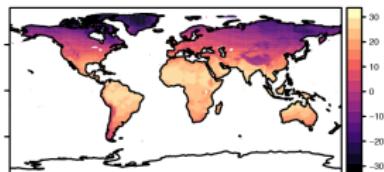
Climate fidelity shapes population trajectories



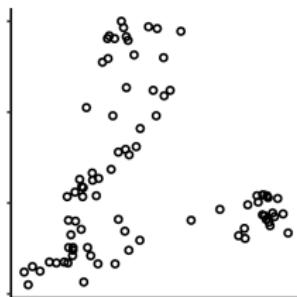
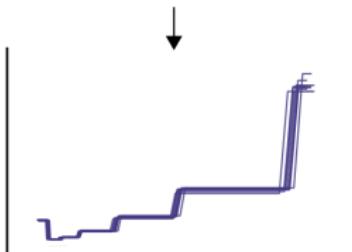
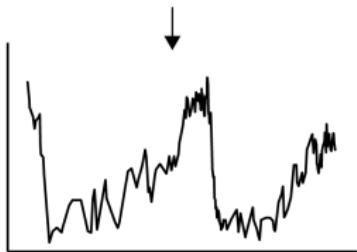
(Pujolar et al. 2022 *Nat. Comm.*)

H_1 : Climate fidelity is negatively correlated with evolutionary potential

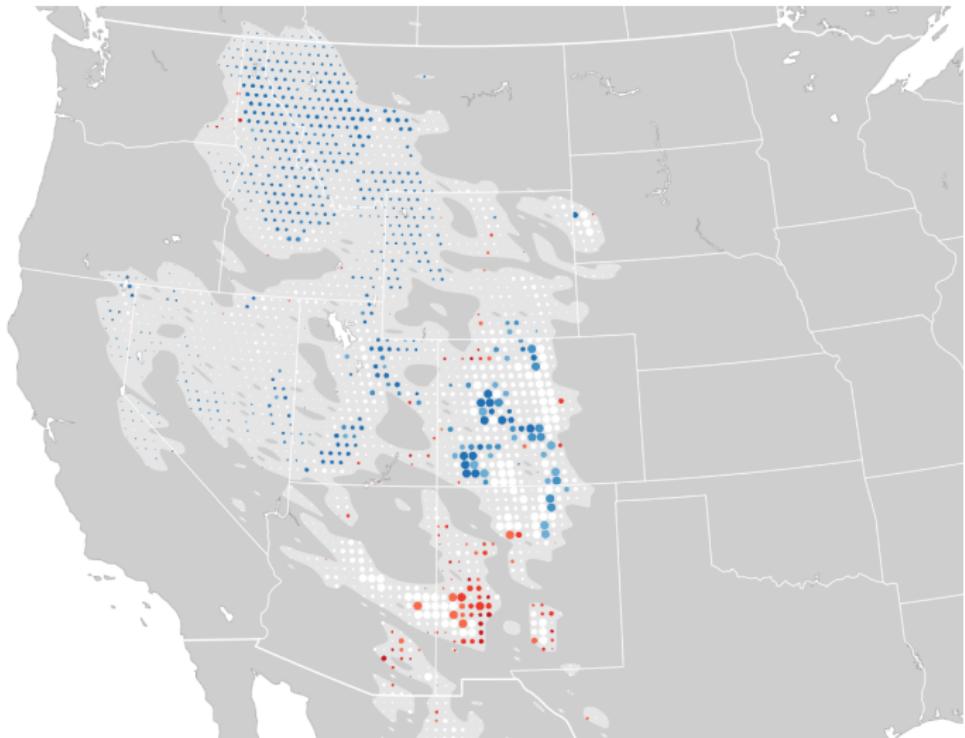
Testing for correlations



atcgactcgta

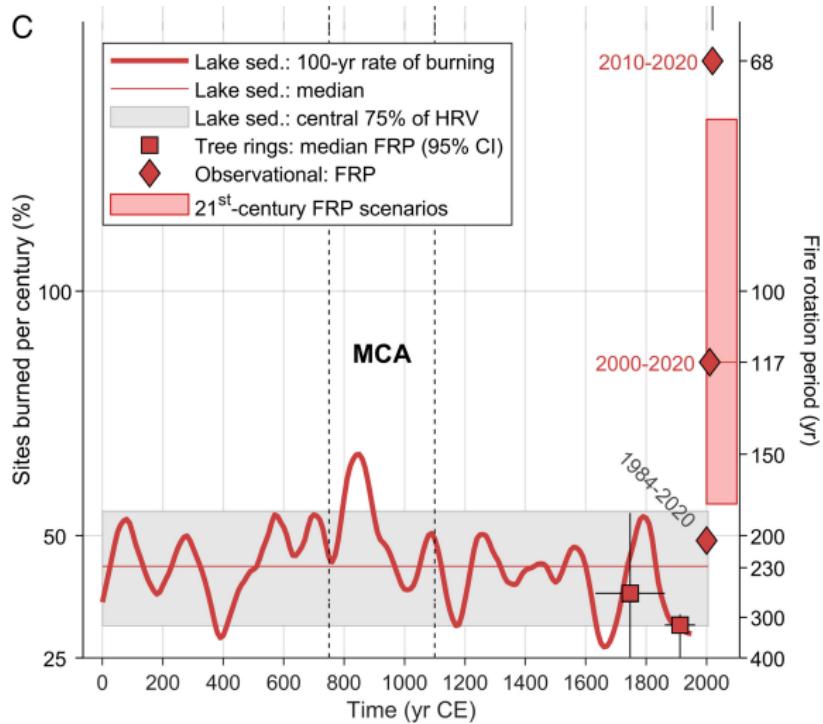


Western forests host niches under threat



(eBird)

Megafires as evolutionary experiment

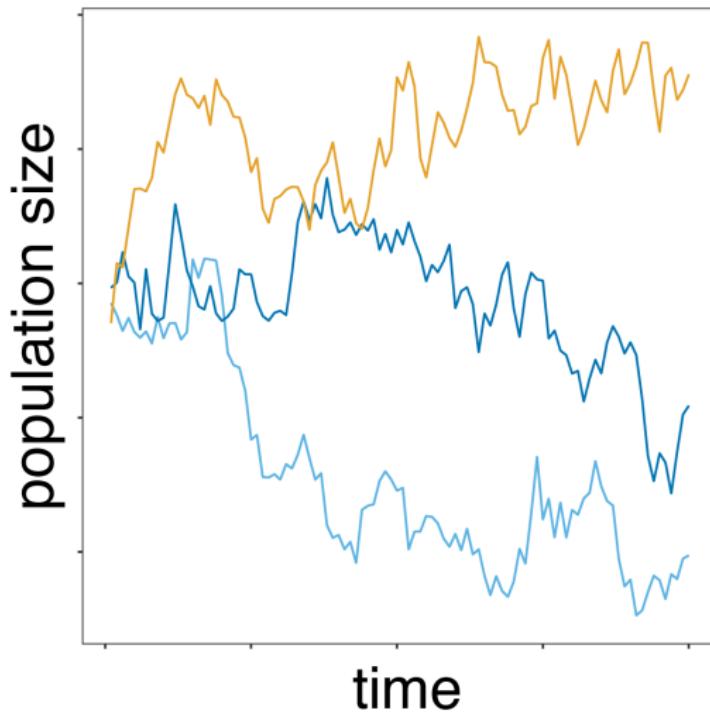


(Higuera et al. 2021 *PNAS*)

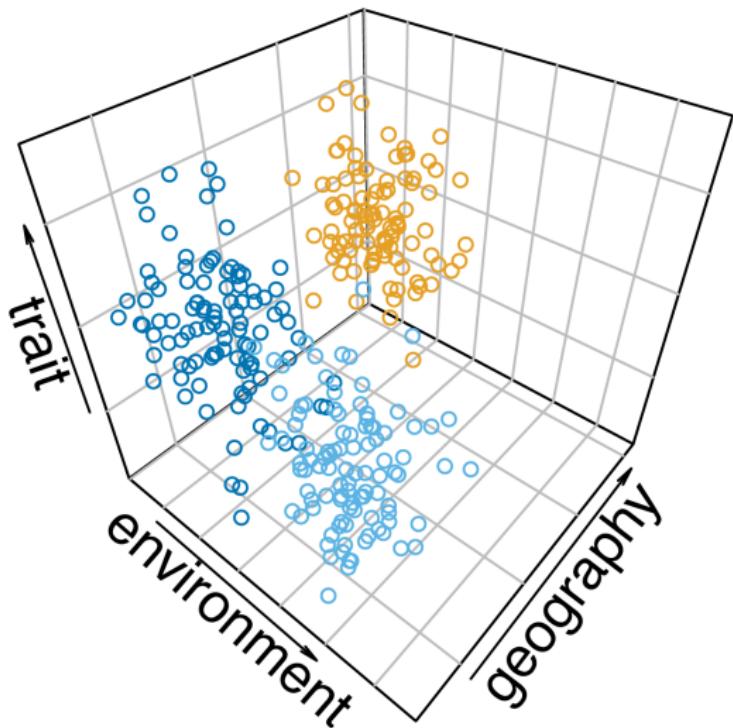
Outline

- ▶ 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 : What can climate fidelity tell us about evolutionary potential?
- ▶ **Q_4 : What is the role of evolutionary thinking in conservation biology?**

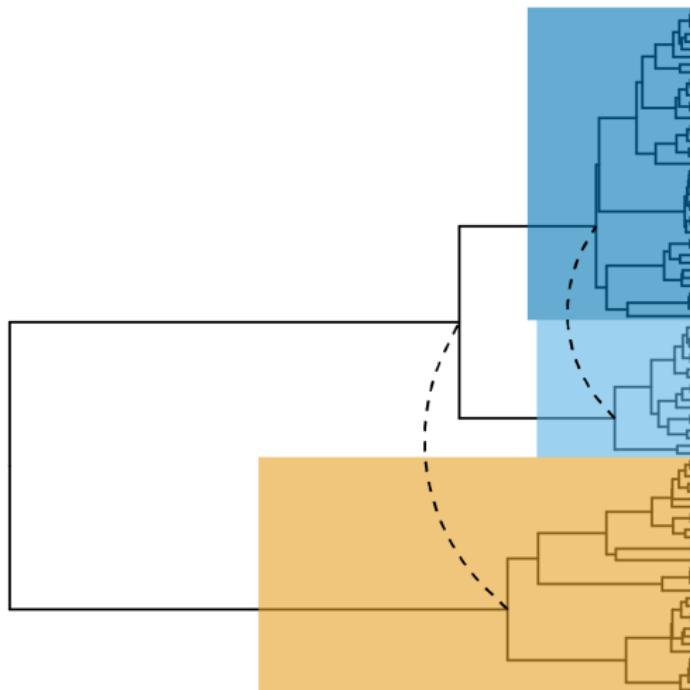
Evolutionary biology can tell us about **evolution**



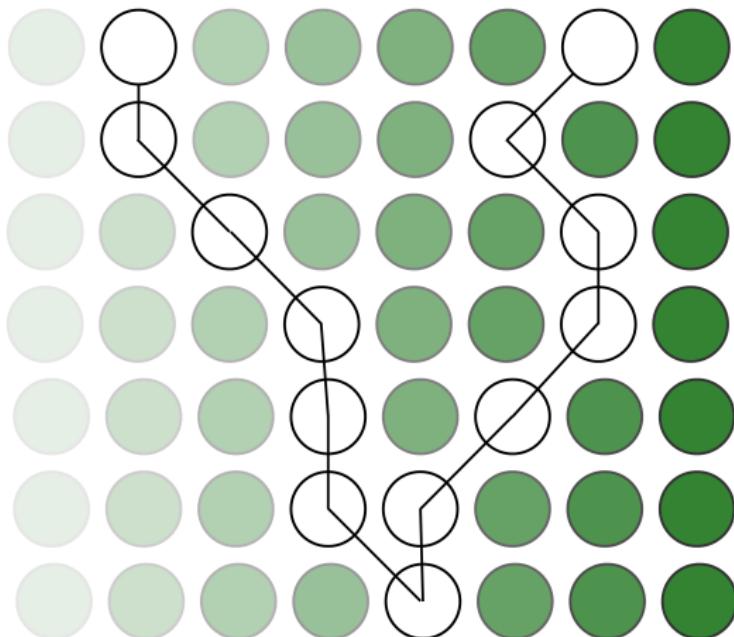
Evolutionary biology can tell us about **traits**



Evolutionary biology can tell us about **values**



Linck Lab @ Montana State University, Fall 2023



Resources

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

References

- ▶ Merriam 1890. *North. Am. Faun.*, 10.5962/bhl.title.86972
- ▶ Wang et al. 2023. *PNAS*, 120(7), e2201946119.
- ▶ Rand 1948. *Evolution*, 2(4), 314-321.
- ▶ Rull 2008. *Molecular Ecology*, 17(11), 2722-2729.
- ▶ Johnson & Marten 1988. *The Auk*, 105(1), 177-191.
- ▶ Linck et al. 2019. *Systematic Biology*, 68(6), 956-966.
- ▶ Flantua et al. 2019. *J. Biogeography*, 46(8), 1808-1825
- ▶ Gavrilets 2003. *Evolution*, 57(10), 2197-2215.
- ▶ Bay et al. 2018. *Science*, 359(6371), 83-86.
- ▶ Linck et al. 2021. *Biology Letters*, 17(10), 20210363.
- ▶ Pujolar et al. 2022. *Nature Communications*, 13(1), 268.
- ▶ Higuera et al. 2021. *PNAS*, 118(25), e2103135118.

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 : Climate fidelity may be inversely correlated with evolutionary potential
- ▶ Q_4 : Evolutionary thinking in conservation biology is about more than adaptative responses