



MINISTÈRE
DE LA TRANSITION
ÉCOLOGIQUE
ET DE LA COHÉSION
DES TERRITOIRES

*Liberté
Égalité
Fraternité*



Séminaire du
plan national d'actions
en faveur du Puffin des Baléares

24 au 26 juin 2024



Pervasive hybridization throughout the evolutionary history of the Balearic shearwater mitigates inbreeding depression

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Séminaire du
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Why genomics?

- Avoids relying on **single markers** for inferring evolutionary relationships

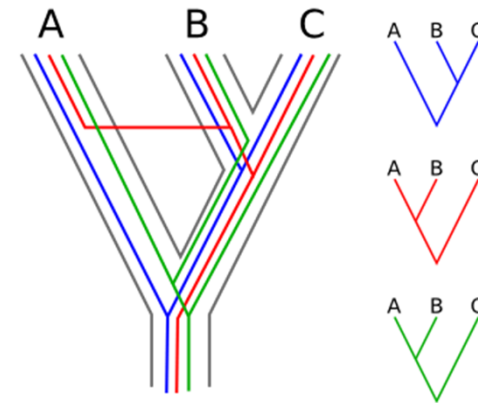
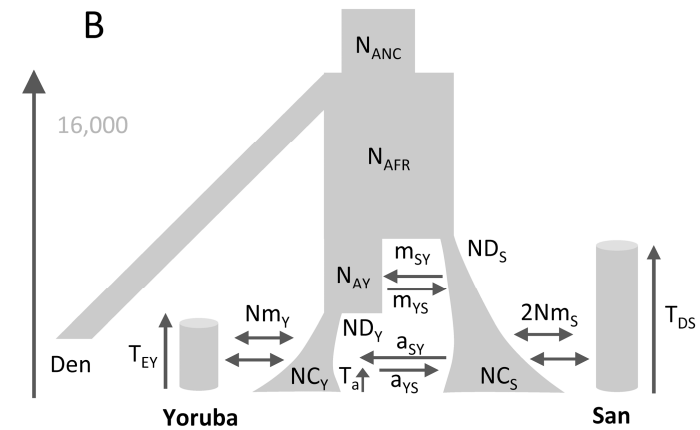


Figure by: Jeremy Yoder

Why genomics?

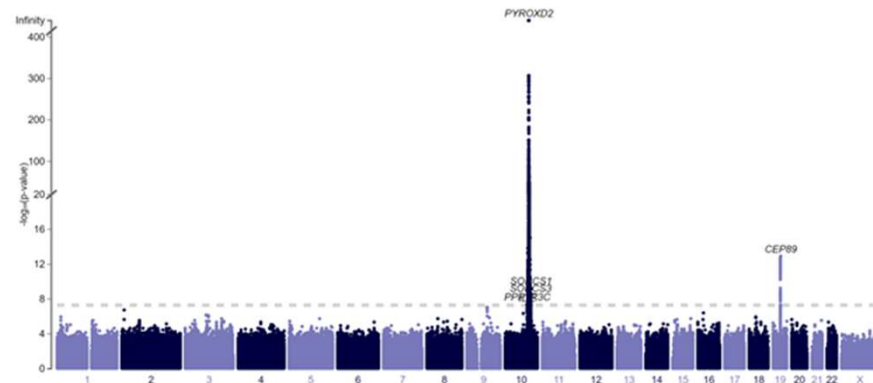
- Avoids relying on **single markers** for inferring evolutionary relationships
- Complex inferences on **demographic history** or **gene flow**



Excoffier et al. 2013

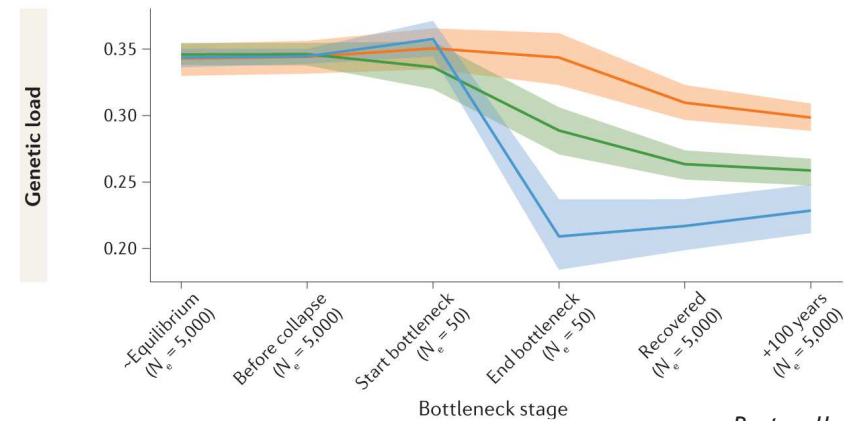
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- Complex inferences on **demographic history** or **gene flow**
- Detection of **genes** under **selection**
- Characterization of footprints of **inbreeding**

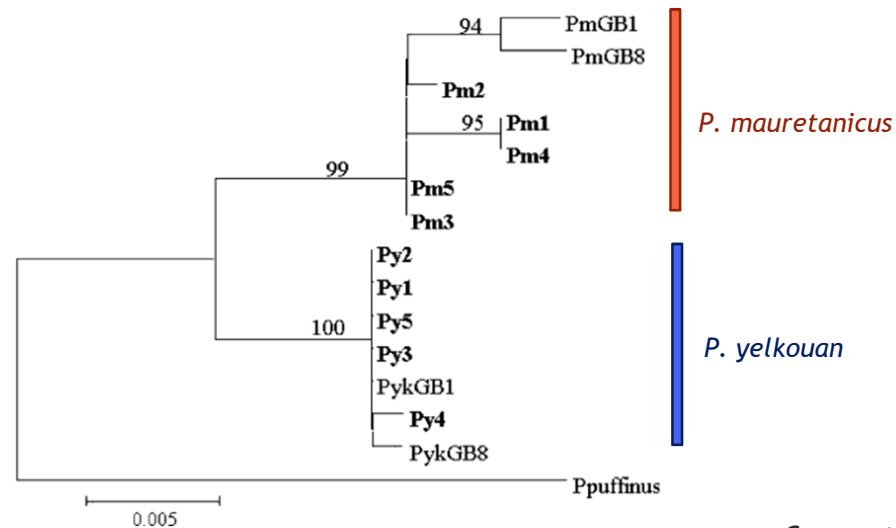


Bertorelle et al. 2022

The evolutionary hystory of Balearic shearwaters

What did we know before working with whole genomes?

1) Divergent mtDNA



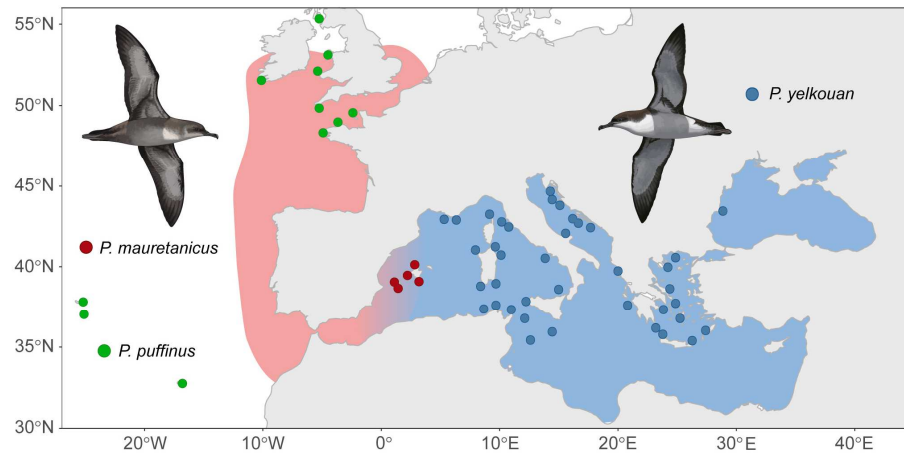
Genovart et al. (2005)

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2) Different morphology & migratory behaviour



The evolutionary hystory of Balearic shearwaters

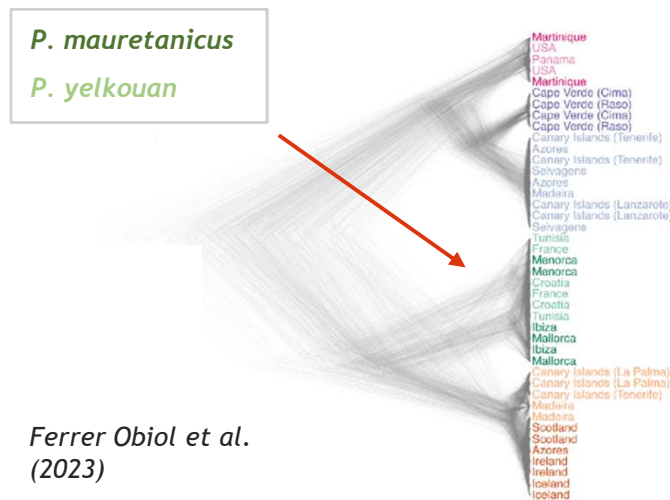
What did we know before working with whole genomes?

1) Divergent mtDNA

2) Different morphology & migratory behaviour

3) No genomic differentiation

P. mauretanicus
P. yelkouan



The evolutionary hystory of Balearic shearwaters

What did we know before working with whole genomes?

1) Divergent mtDNA

2) Different morphology & migratory behaviour

3) No genomic differentiation

4) Hybrid population in Menorca?

“Menorcan shearwaters”

~ 400 breeding pairs

Intermediate morphology and migratory behaviour

Both mtDNA haplotypes

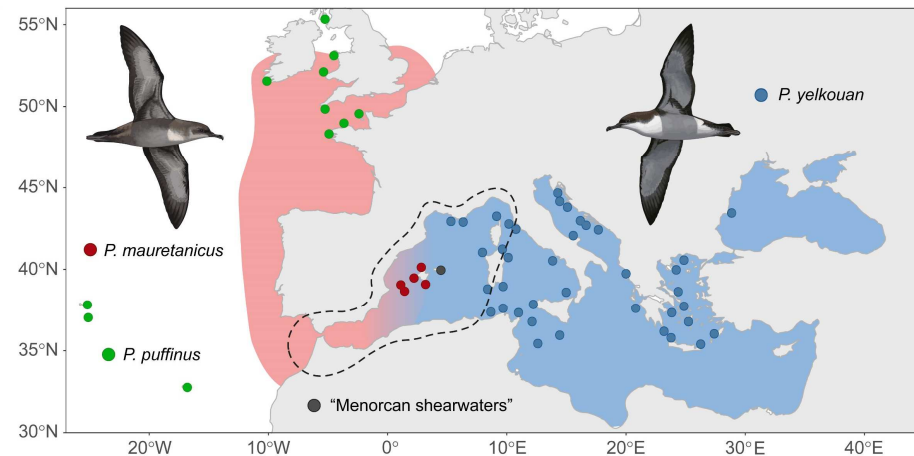


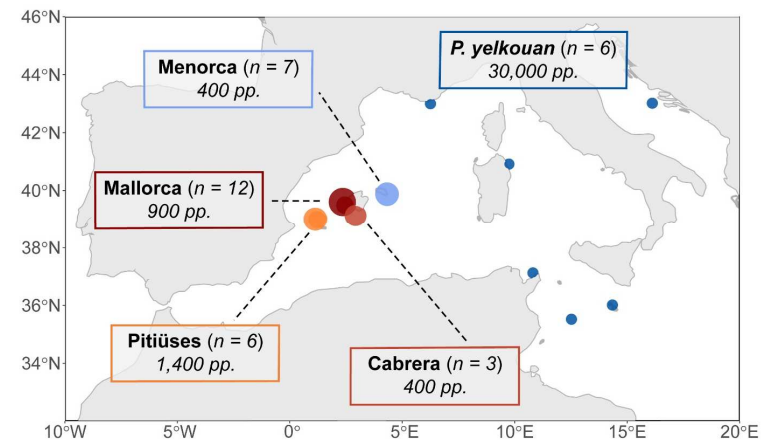
Photo by: Arnoud B. van den Berg

Objectives & sampling

1. Place the evolutionary history of Mediterranean *Puffinus* in an accurate **spatiotemporal context**
2. Characterize the history and extent of **gene flow** between *P. mauretanicus* and *P. yelkouan*
3. Identify **candidate genes** that might be driving morphological/migratory differentiation between both shearwaters
4. Evaluate whether demographic collapse has caused a rise in **homozygosity and genetic load** in *P. mauretanicus*

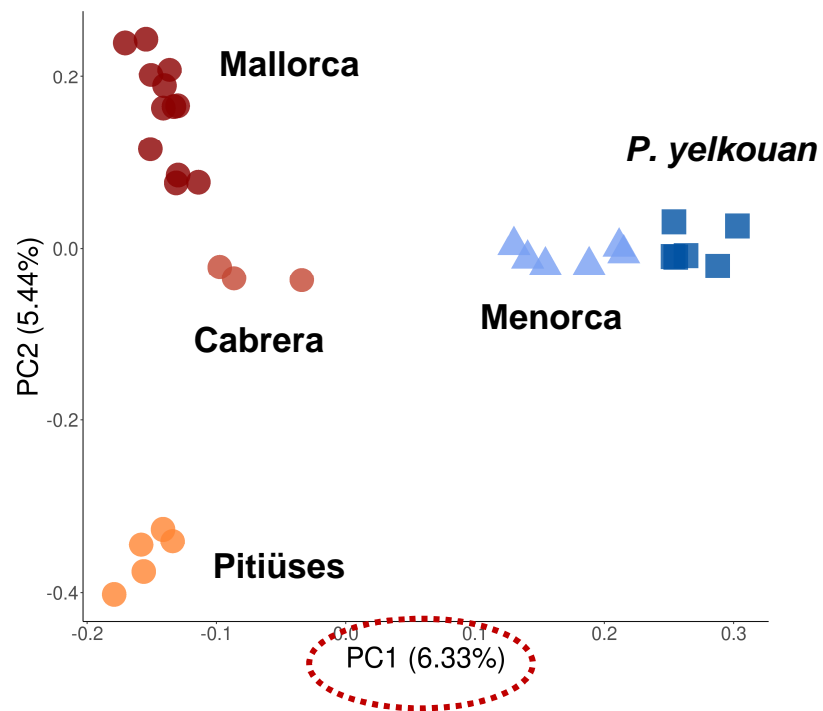
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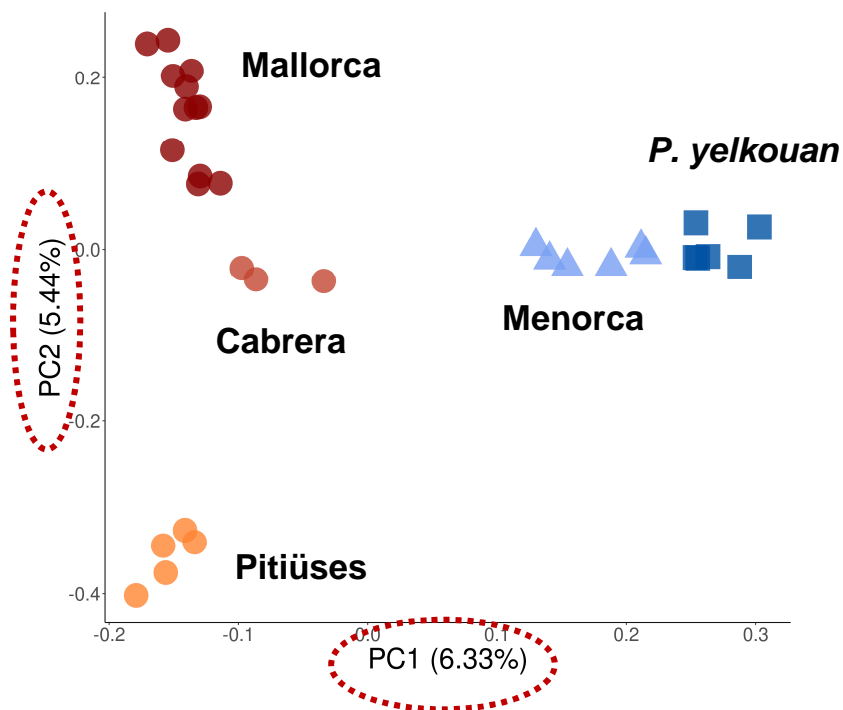
+ 2 individuals of *P. puffinus*

Population structure



1) Very weak differentiation between species

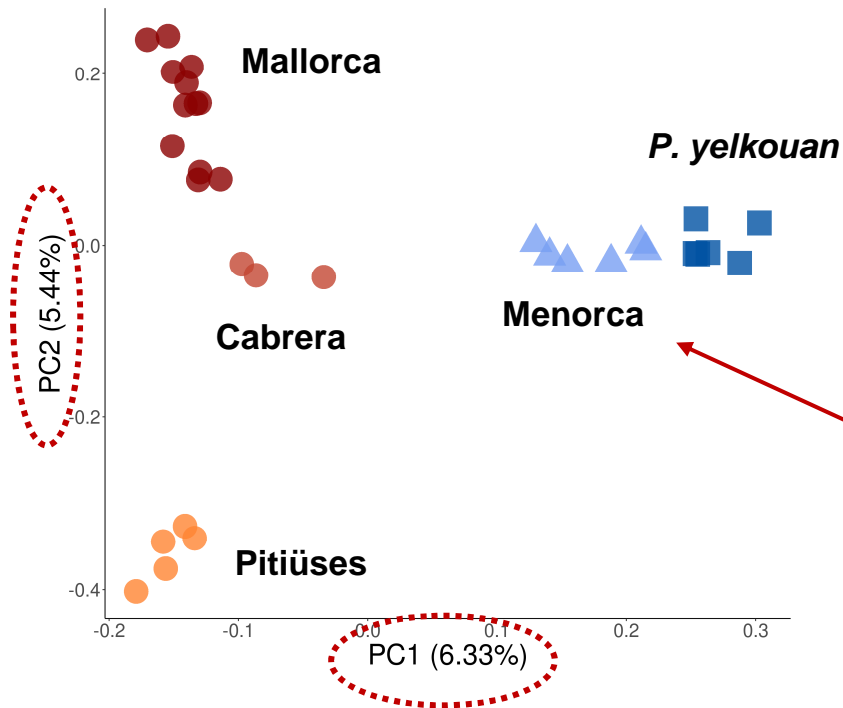
Population structure



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Population structure

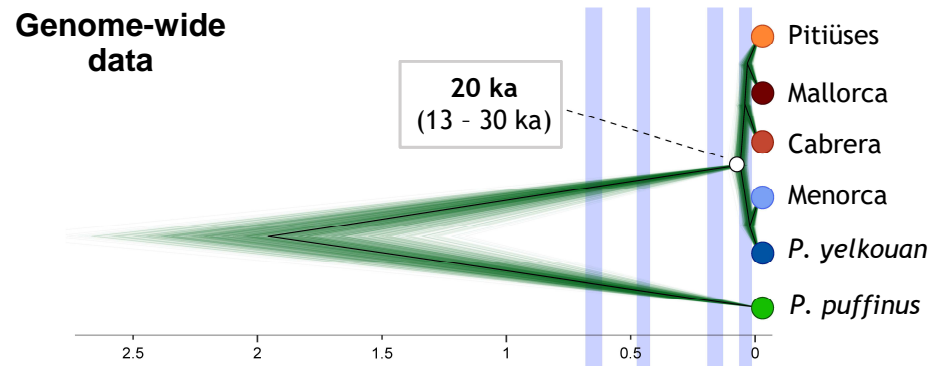


1) Very weak differentiation between species

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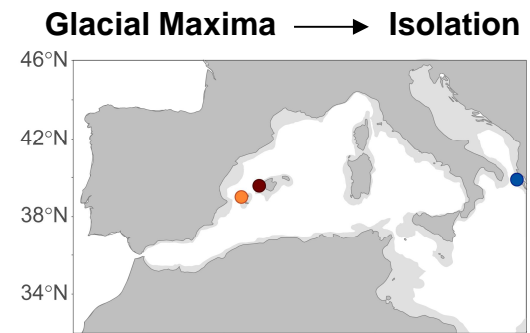
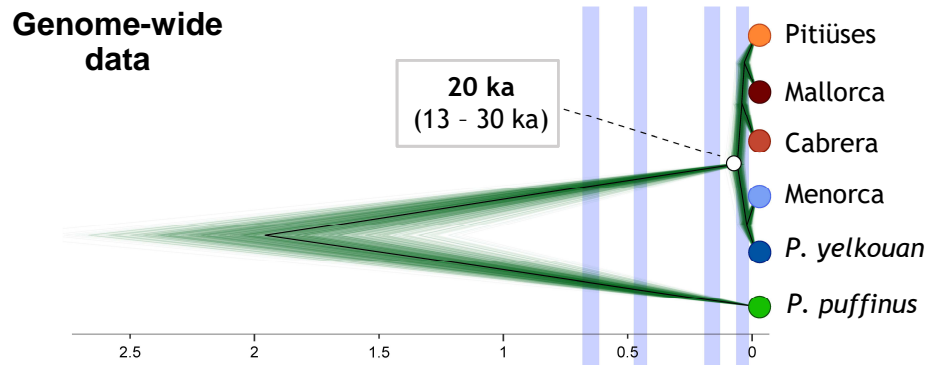
3) “Menorcan shearwaters” are *P. yelkouan*

Divergence time between species



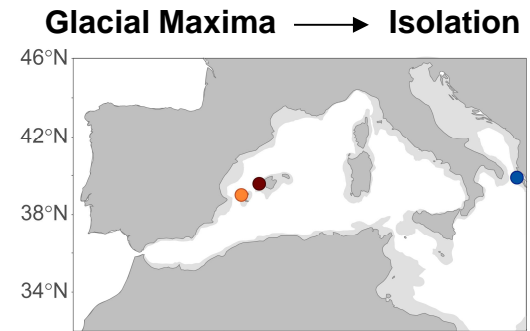
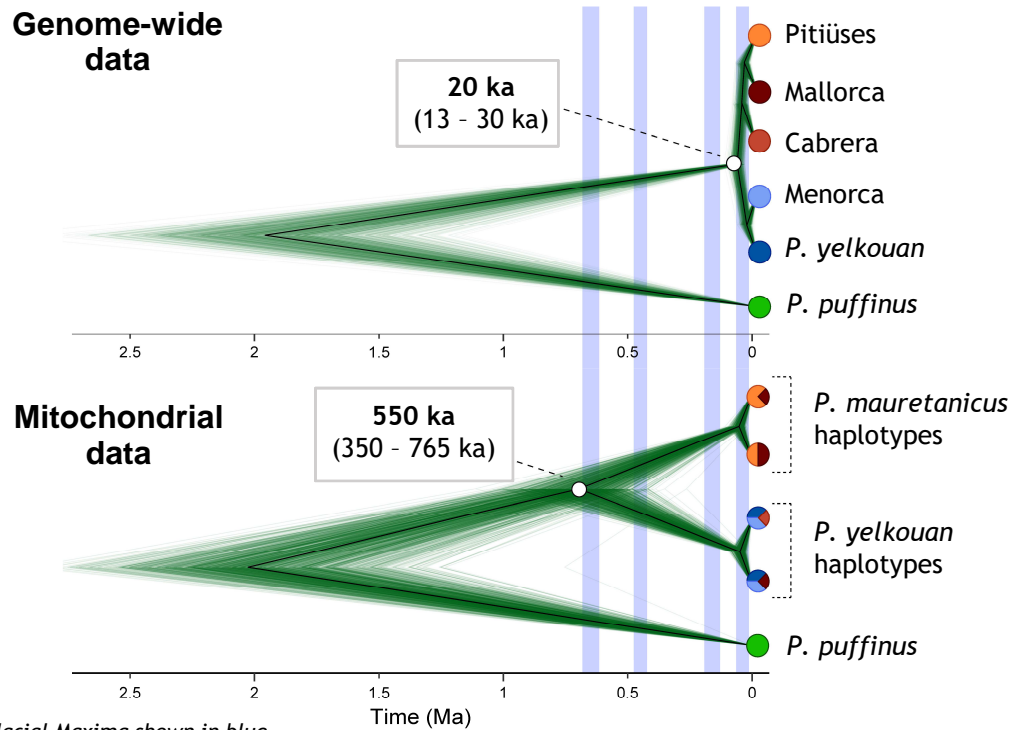
* Glacial Maxima shown in blue

Divergence time between species

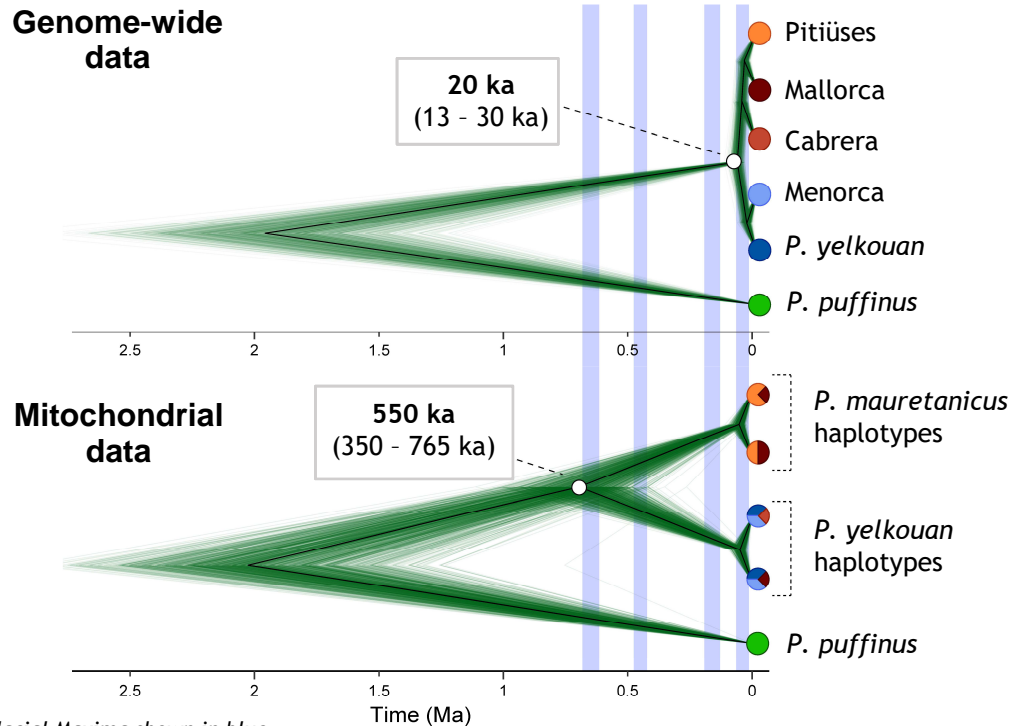


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Divergence time between species

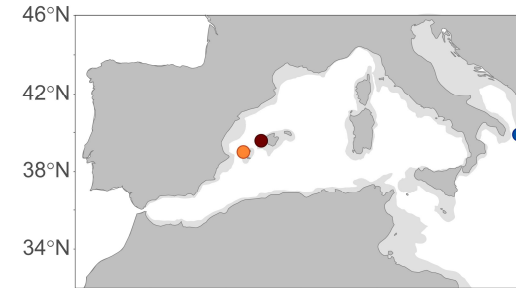


Divergence time between species

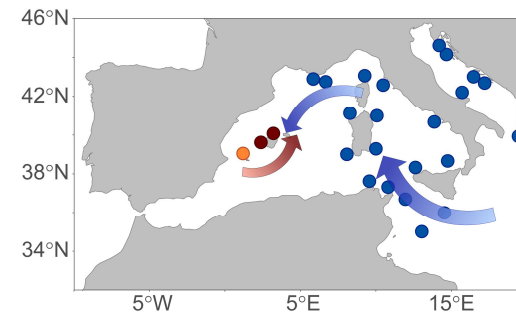


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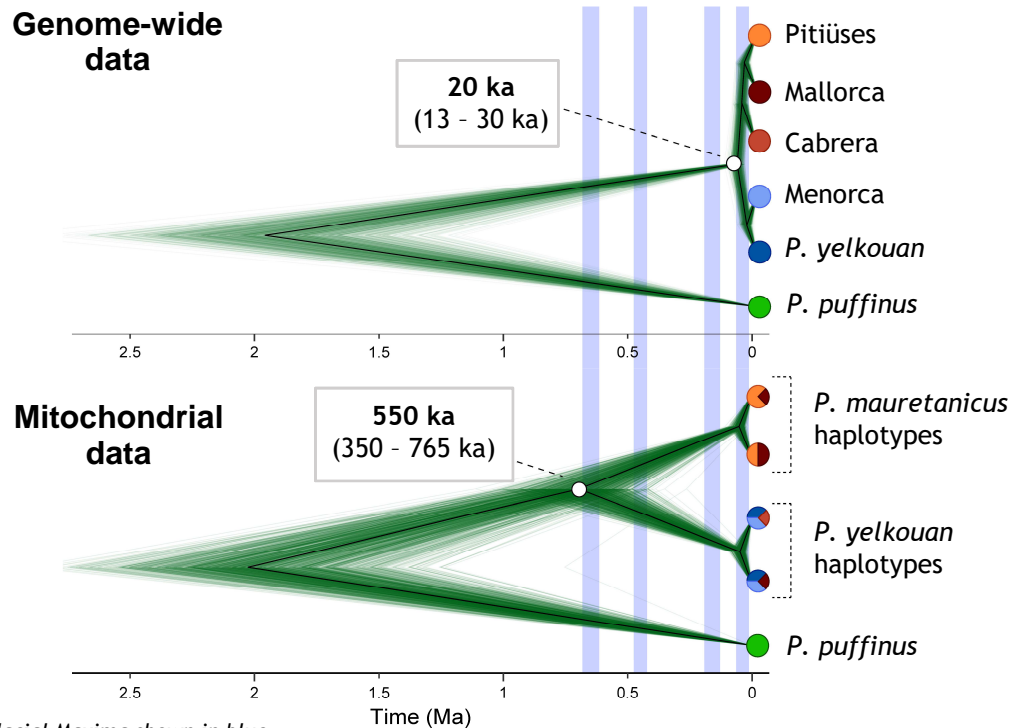
Glacial Maxima → Isolation



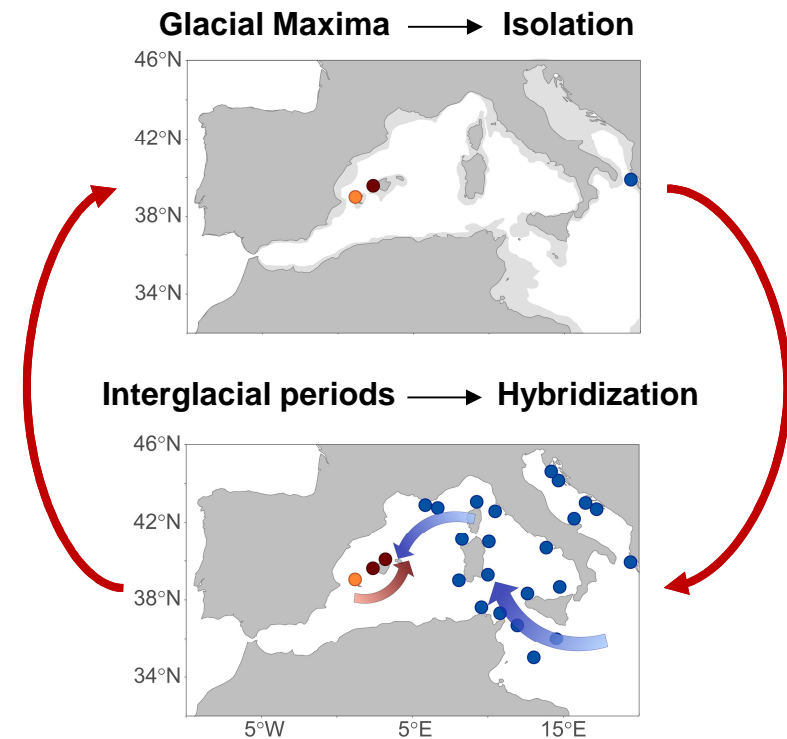
Interglacial periods → Hybridization



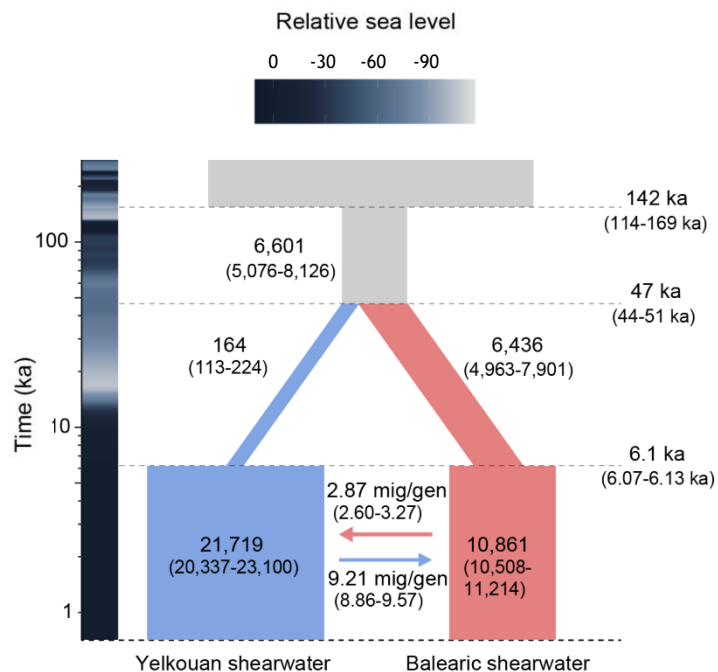
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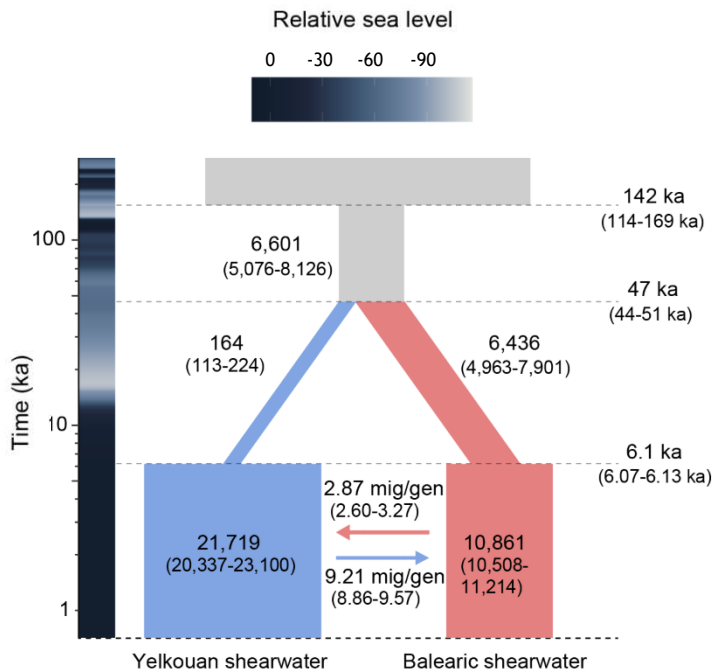


Demographic history and hybridization



- Isolation associated to **bottlenecks** during LGM
- Interglacial expansions cause **widespread hybridization** through secondary contact

Demographic history and hybridization

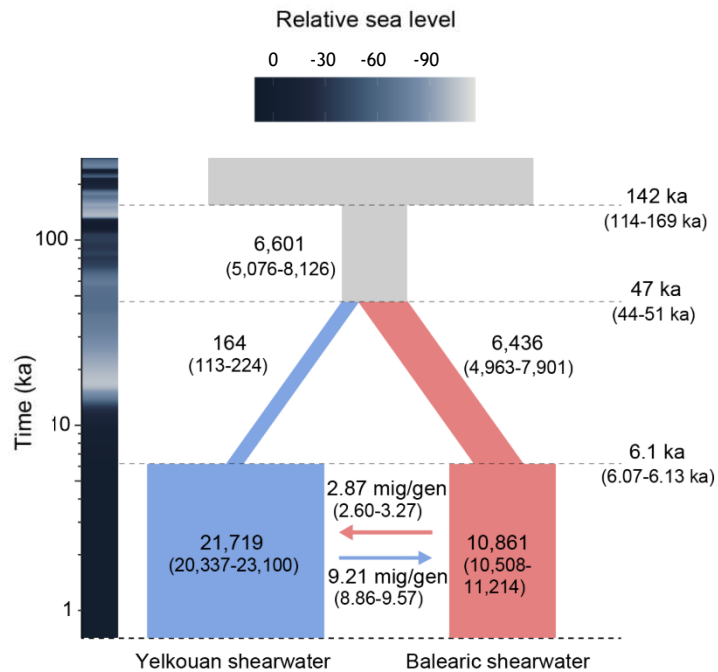


- Isolation associated to **bottlenecks** during LGM
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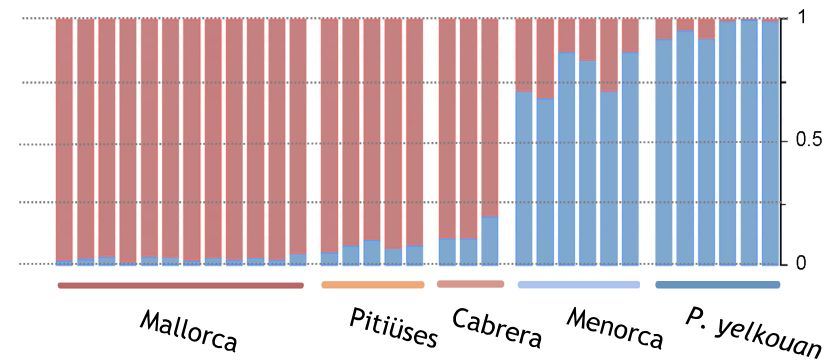


No fixed differences out of the 1.2×10^9 base pairs of the genome!

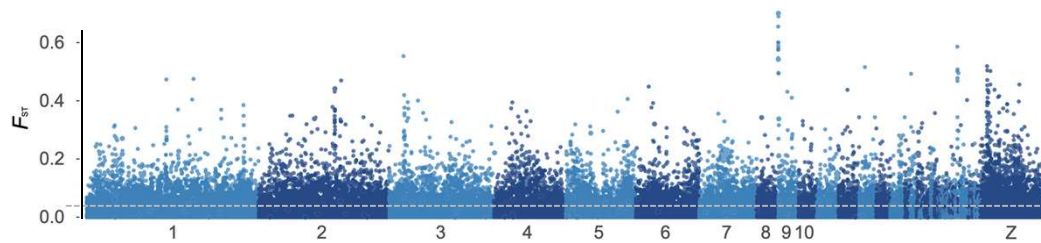
Demographic history and hybridization



- Isolation associated to **bottlenecks** during LGM
- Interglacial expansions cause **widespread hybridization** through secondary contact
- Hybridization most extensive in **Menorca** and **Cabrera**

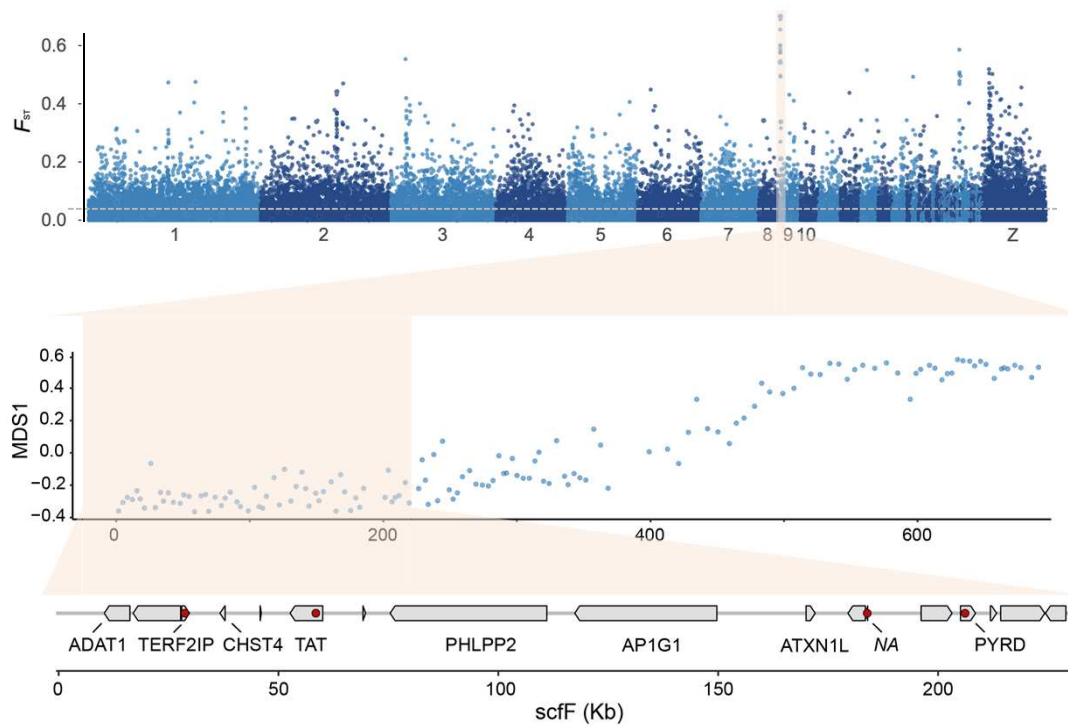


Genes driving differentiation in Mediterranean *Puffinus*



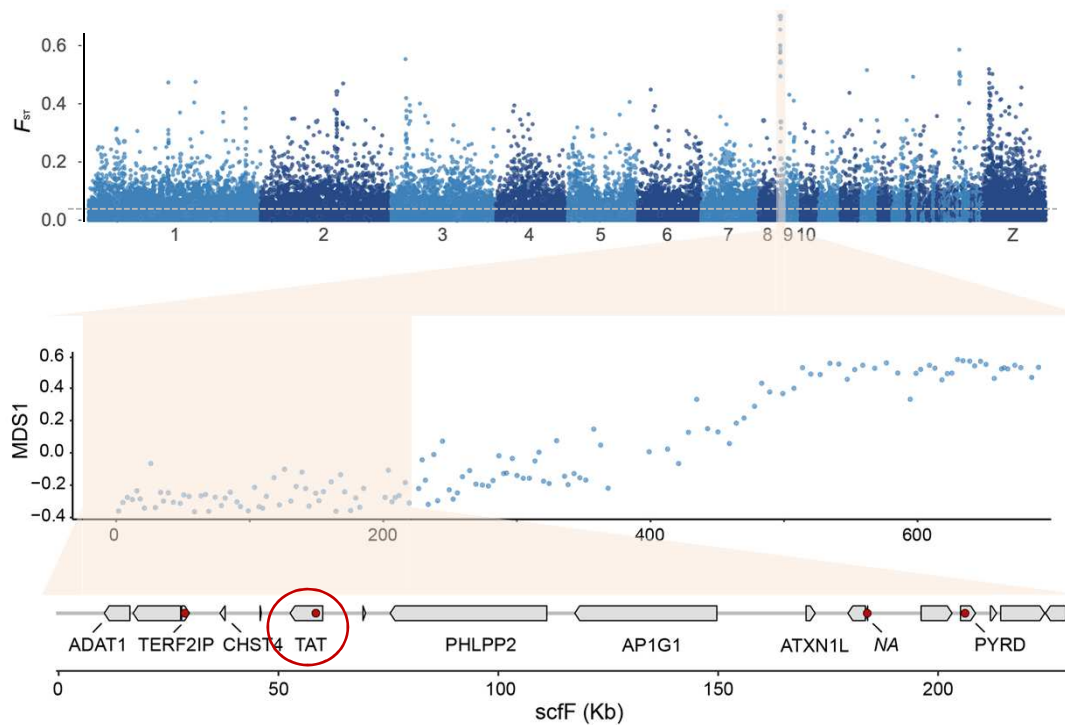
- Few differentiated genomic regions – potentially under divergent selection

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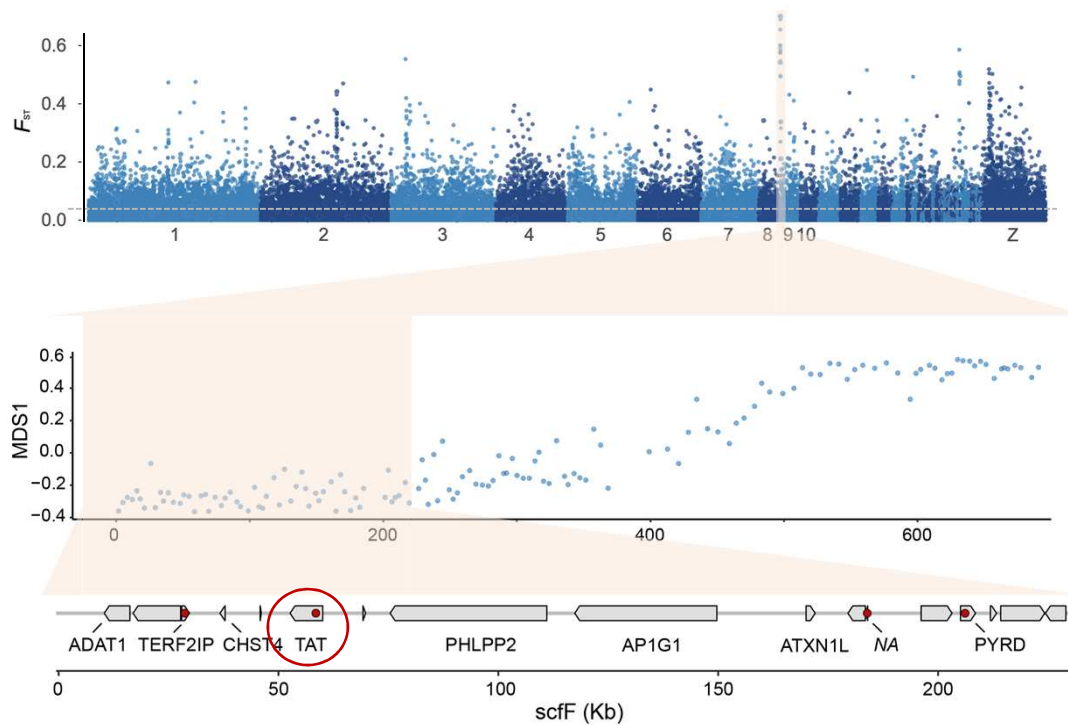


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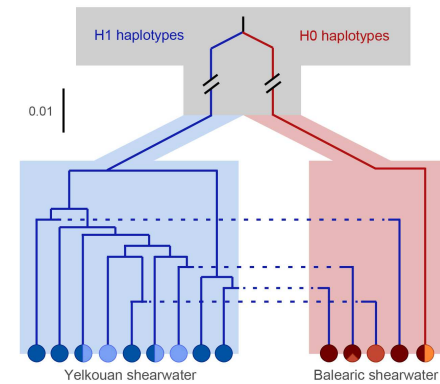
TAT – a promising candidate to underlie differences in **migratory** strategy

- Involved in **pre-migratory hyperphagia** in passerines

Genes driving differentiation in Mediterranean *Puffinus*



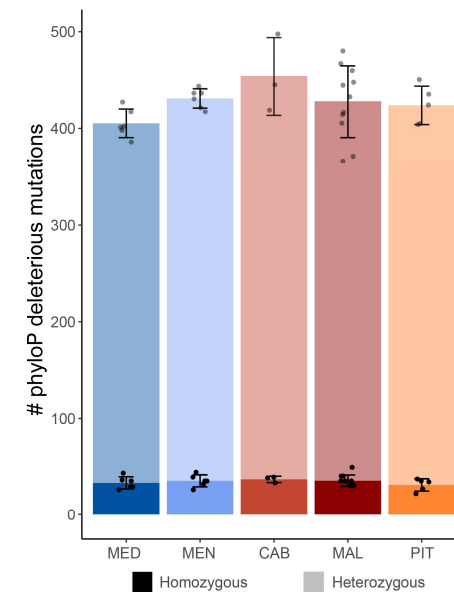
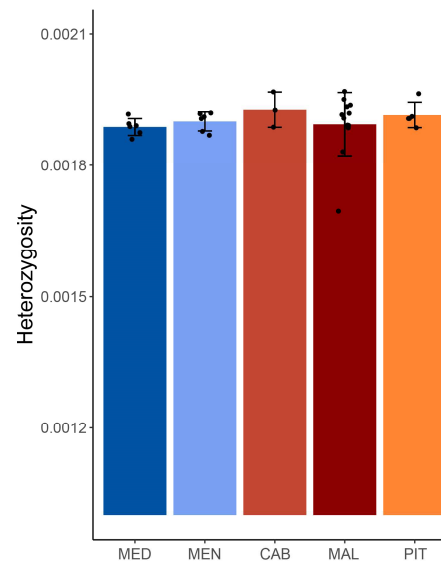
TAT – a promising candidate to underlie differences in **migratory** strategy



- Even these adaptive genes can be introgressed between species

Footprints of inbreeding

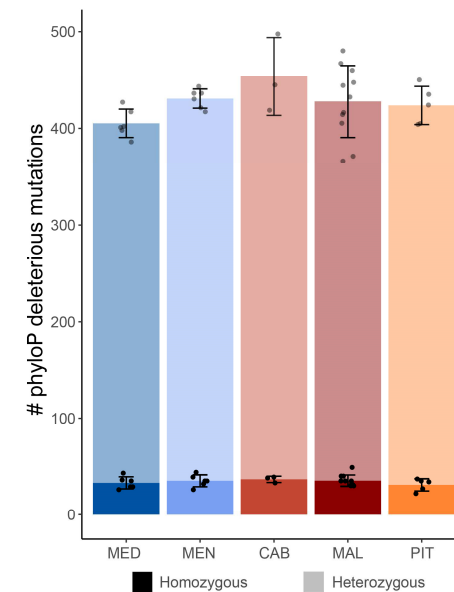
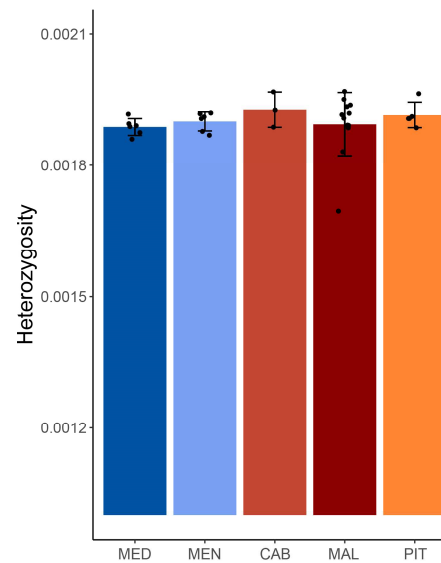
- **No significant differences** across Mediterranean populations
- Most deleterious mutations are **shared** between species



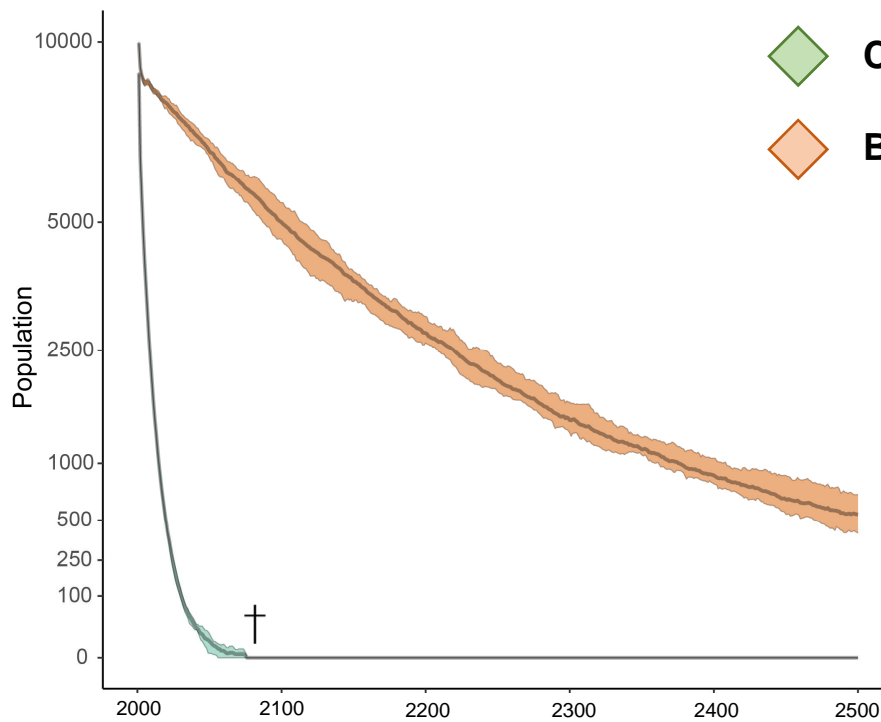
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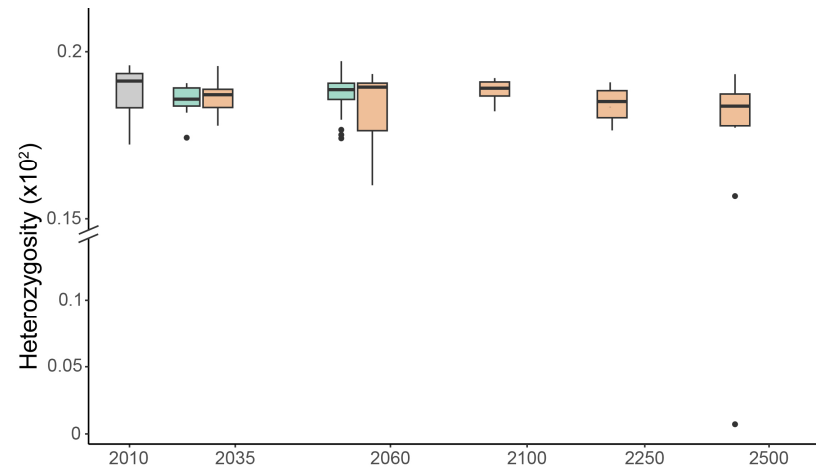
Hybridization mitigates inbreeding
in the Balearic shearwater by
introducing genetic diversity



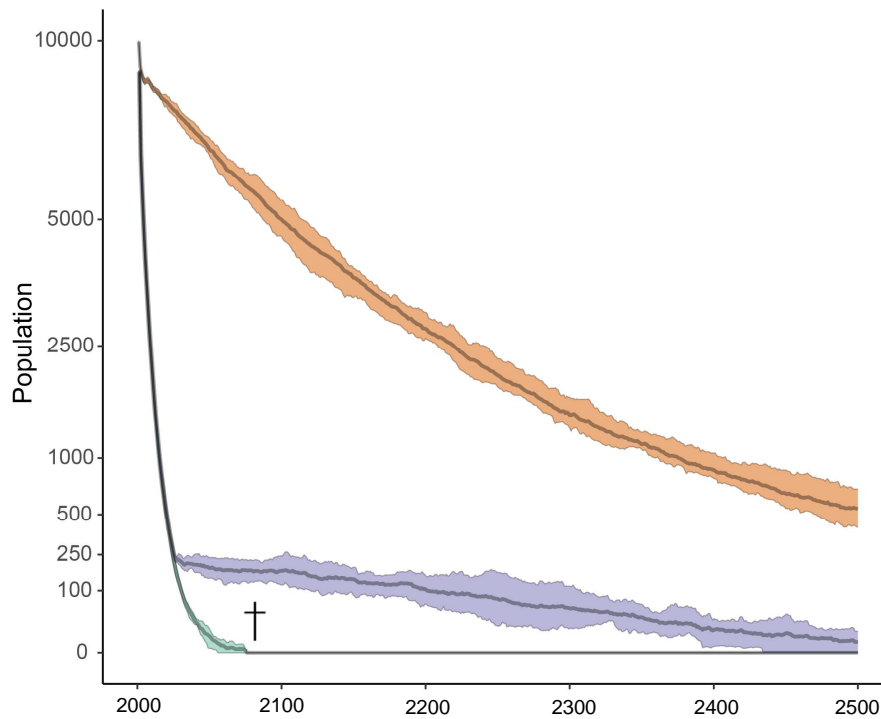
Forward simulations



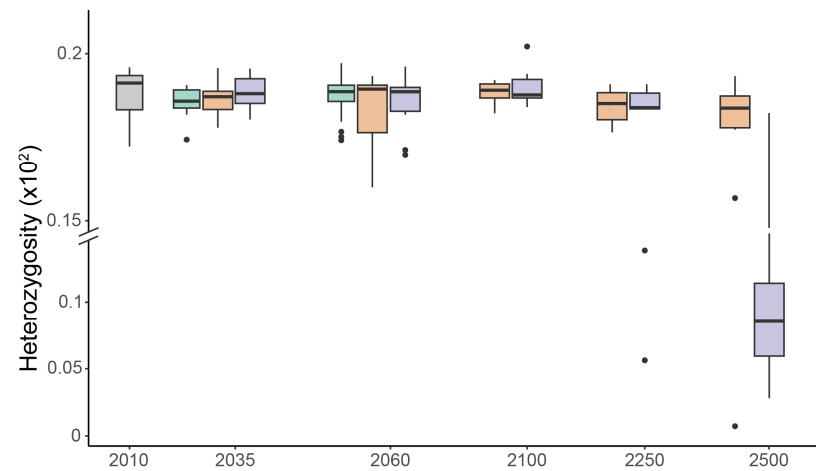
- ◇ **Current projections** → extinction before inbreeding risk
- ◇ **Bycatch reduction** → stable heterozygosity



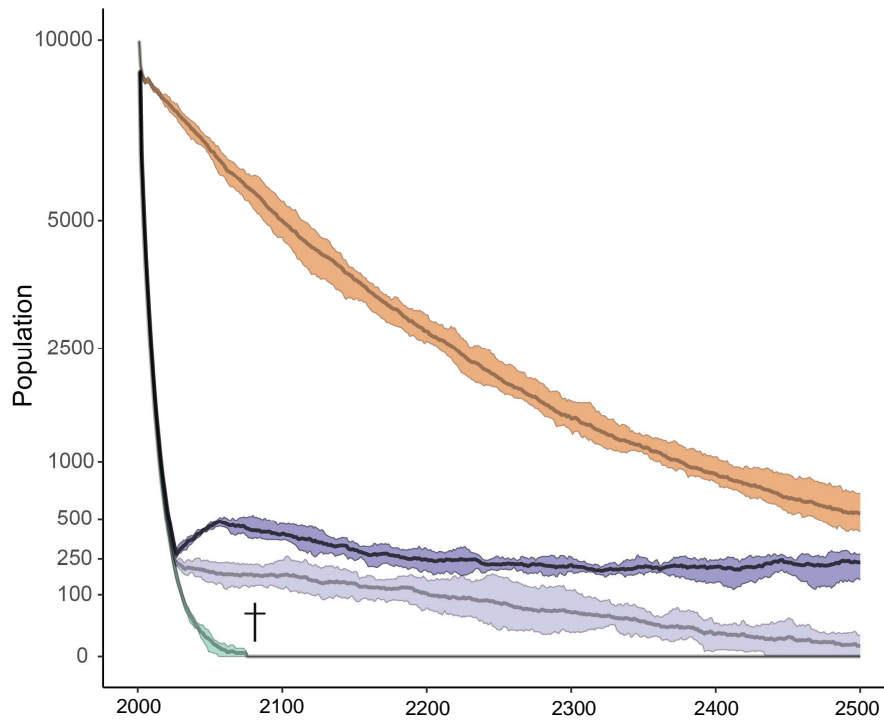
Forward simulations



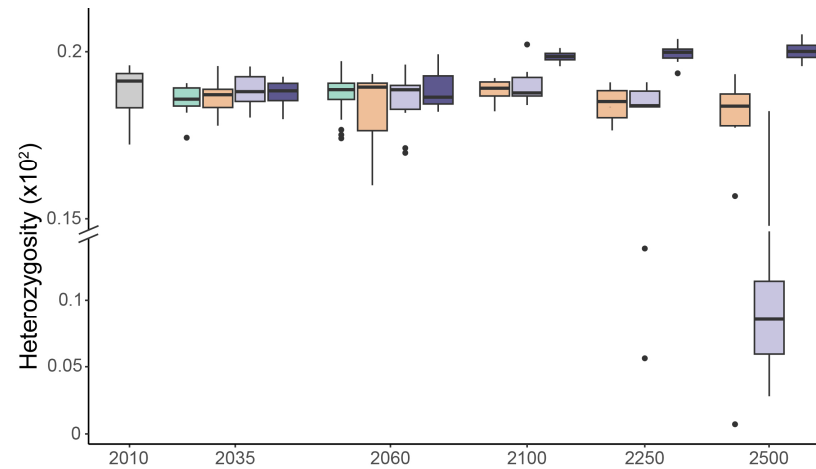
Delayed bycatch reduction → drastic drop in heterozygosity



Forward simulations



**Delayed bycatch reduction +
hybridization → no risk of inbreeding**



Conclusions

1. **Very weak genomic differentiation** between Balearic and Yelkouan shearwaters
2. **Menorcan shearwaters** are a population of Yelkouan shearwater
3. **Glacial maxima** have caused repeated events of bottlenecks/differentiation, while **interglacial periods** have caused population expansions/hybridization.
4. **Hybridization** is currently pervasive, and most extensive in **Menorca** and **Cabrera**.
5. Hybridization has allowed the exchange of **genes** that might grant **adaptive potential** in front of climate change.
6. Hybridization has **prevented inbreeding** in the Balearic shearwater.
7. Conservation plans should contemplate the **protection of hybrid colonies** to guarantee genetic diversity in face of **future bottlenecks** if measures to reduce bycatch are delayed.

Acknowledgements



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- Karen Bourgeois
- Maite Louzao



Seabird
Ecology
Lab

