WHERE DID ARCTIC-ALPINE MOSSES SURVIVE IN A FROZEN EUROPE?

Insights from a multispecies coalescent analysis

Alice Ledent, Aurélie Désamoré, Benjamin Laenen, Jairo Patiño, Stuart F. McDaniel, Patrick Mardulyn and Alain Vanderpoorten

Introduction

Impact of global warming on species distribution ?

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→ Quaternary glacial periods (Hewitt, G.M. 1996, 1999, 2000)

- Last Glacial Maximum (LGM: 26,000 – 19,000 years BP) = the most virulent

Fundamental biogeographic hypothesis in Europe

- Impact of LGM on species distribution
- Southern *refugia* hypothesis
- Temperate species
  - Small mammals (Hewitt, G. *Nature*, 2000)
  - Woody plants (Petit, R.J. *Science*, 2003)

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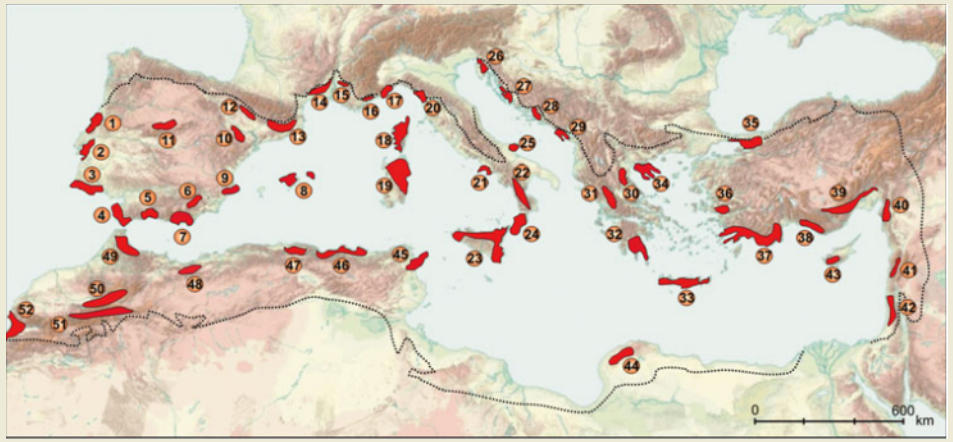
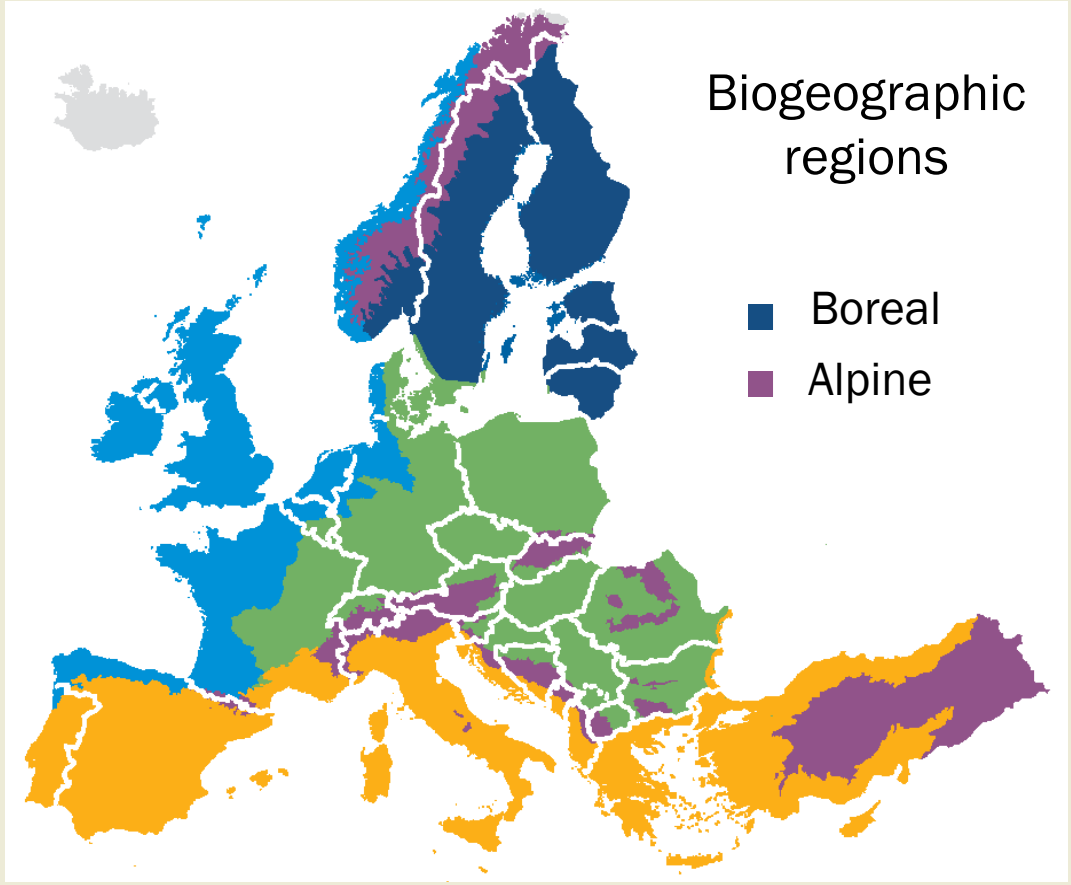


Introduction

- Arctic-Alpine distribution area



- Regions mainly covered by ice during the Pleistocene glacial periods
- Disjunct distribution
  - *Arctic/Boreal = Fennoscandia*
  - *Alpine = Alps, Carpathians, Rhodopes,…*
- Poorly studied but highly important

→ Where did they survive during the glacial periods, especially the LGM?

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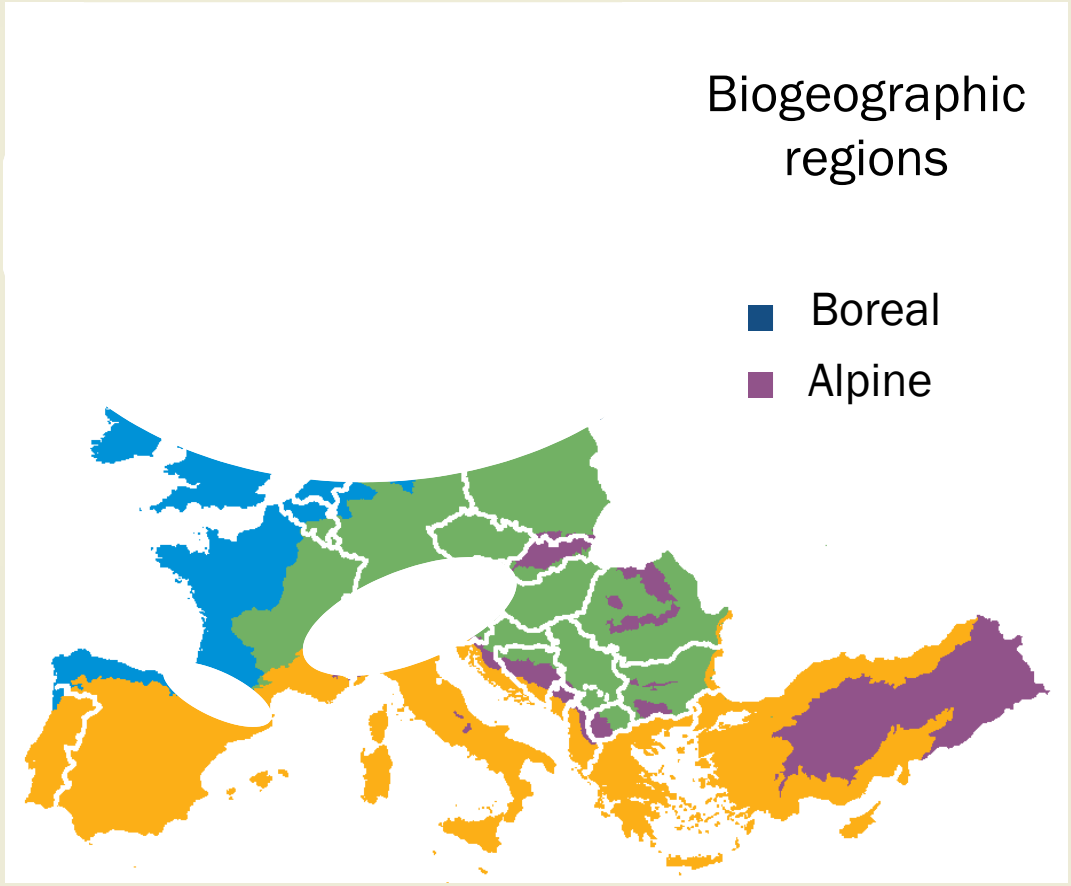

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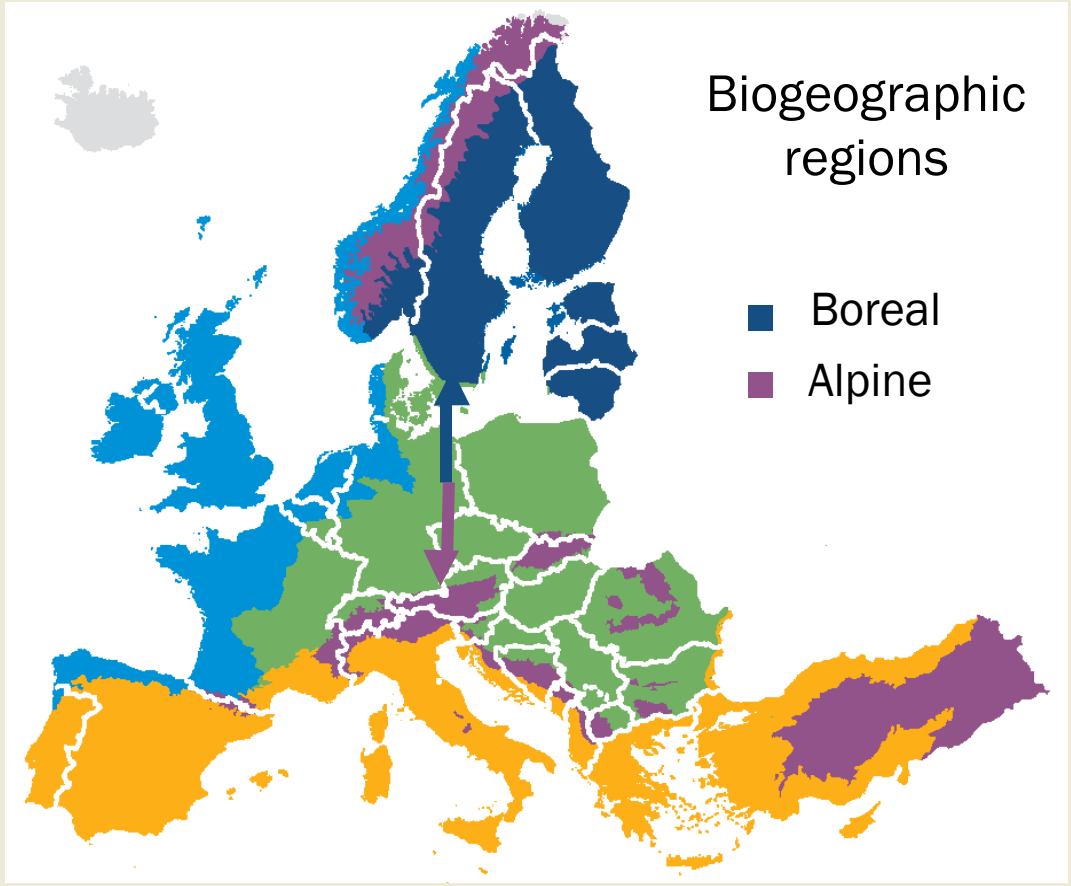

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Major biogeographic hypotheses

- ***Tabula rasa* hypothesis** (Birks 2008, Skrede 2006)
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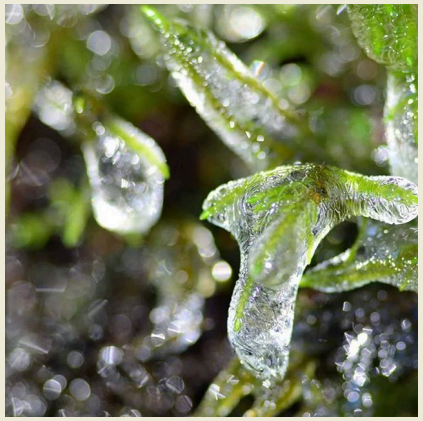

What about bryophytes?

- Dominant elements in Arctic-Alpine vegetation

  (Roads, E. 2014)

- High cold tolerance (Furness, S.B. and Grime, J.P. 1982)
- Ability to survive in ice and regenerate (Lafarge, C. 2013, Roads, E. 2014)

→ Good candidate for the *Nunatak* hypothesis

- High dispersal capacities
- Ability to cross oceans (Stenøien, H.K. 2010)

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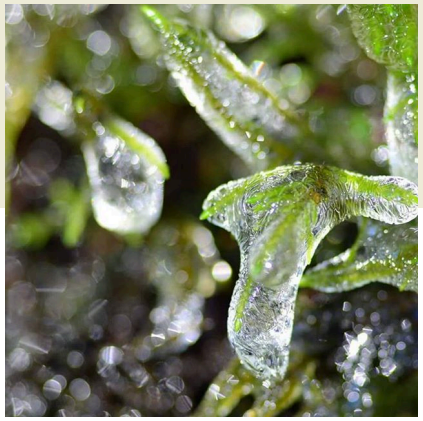

Material and methods

I
Sampling and data analysis

- 3 species
  - *Amphidium lapponicum*
  - *Timmia austriaca*
  - *Timmia bavarica*

- Sampled across 5 populations
  - Fennoscandia ( )
  - Iced Alps ( )
  - Non iced Alps ( )
  - Lowland ( )
  - Out (not represented here)

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Material and methods

I

Sampling and data analysis

II

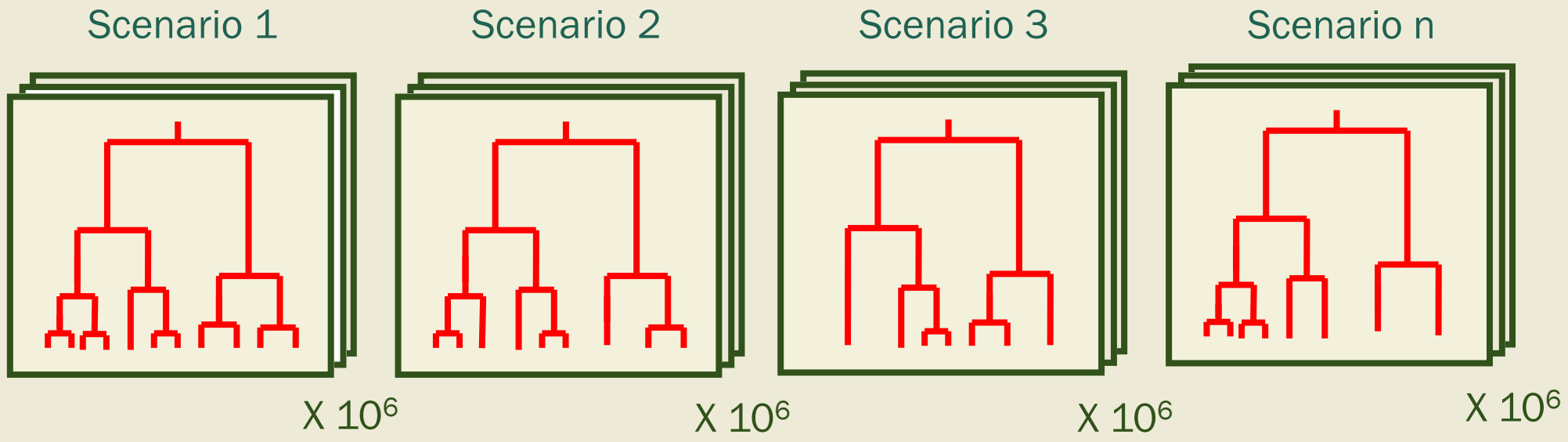
Approximate Bayesian Computation analysis (ABC)

3 steps

Material and methods

1. Simulation of alleles genealogies

- Coalescence technique
- Under the constraint of different demographic scenarios
- Through definition of *prior* range of values of demographic parameters
  - *Migration rates*
  - *Effective population size*



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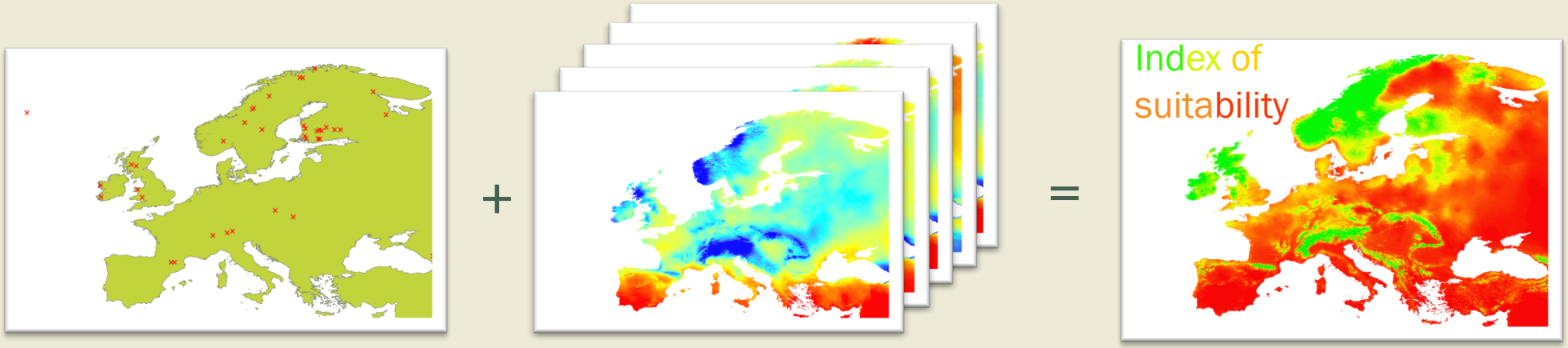

Dependent data + Independent data = Species Distribution model (SDM)

Material and methods

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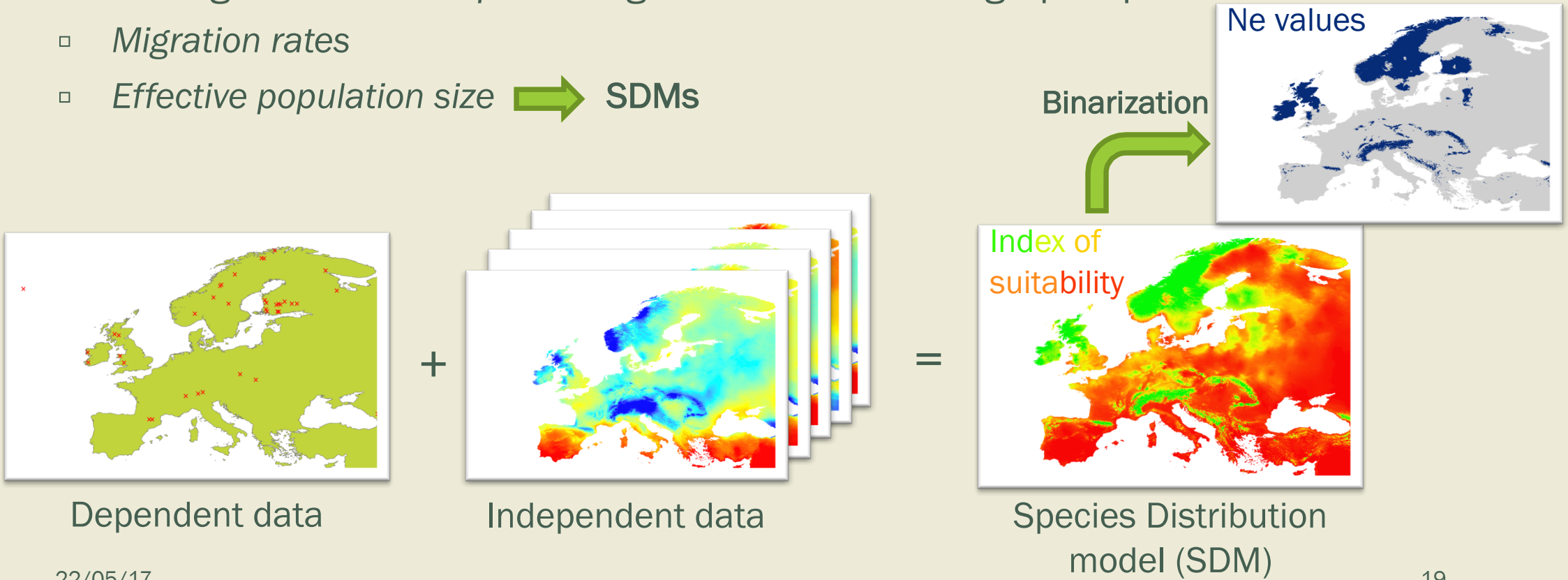
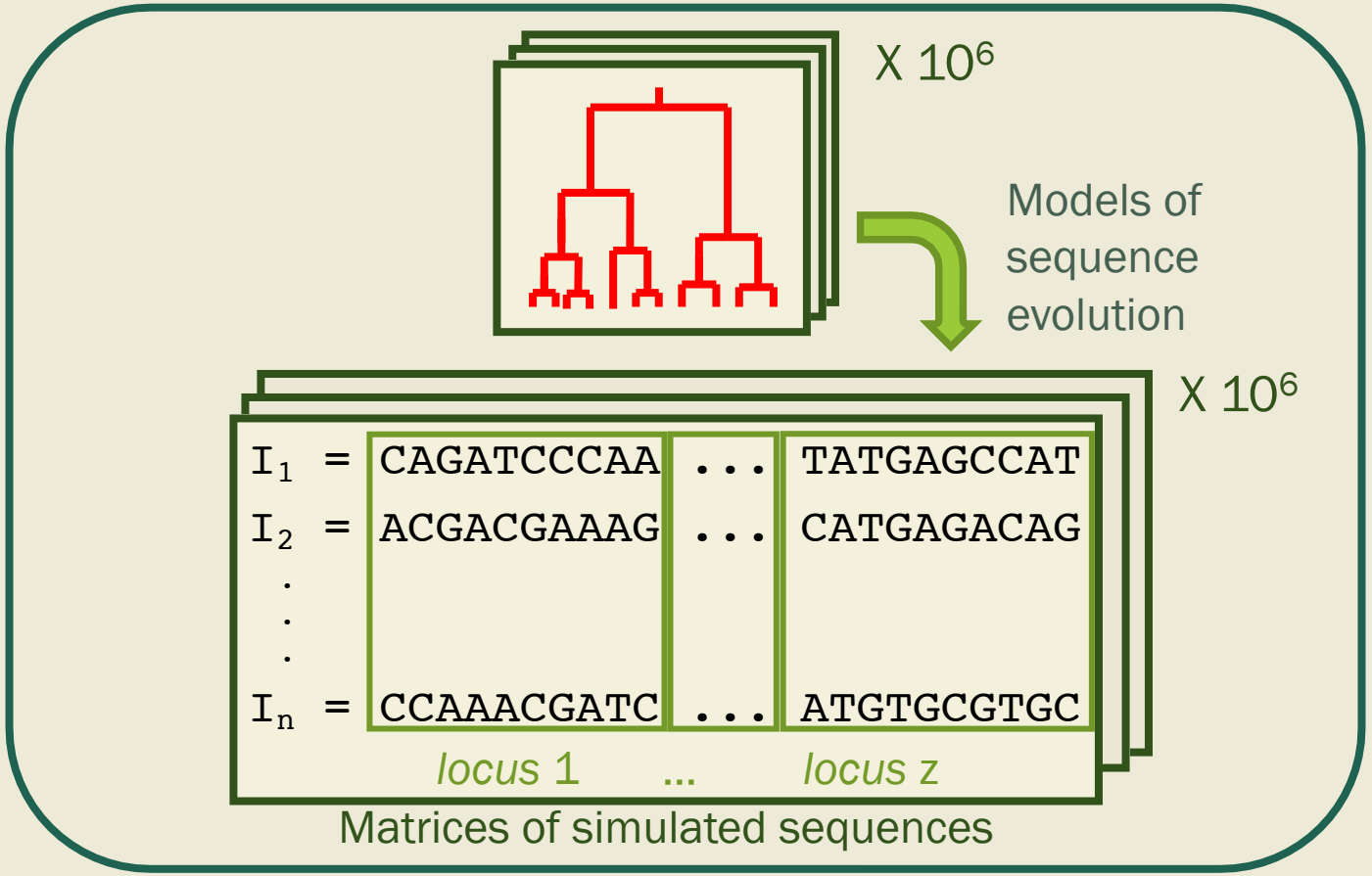


Material and methods

2. Matrices of sequences simulation

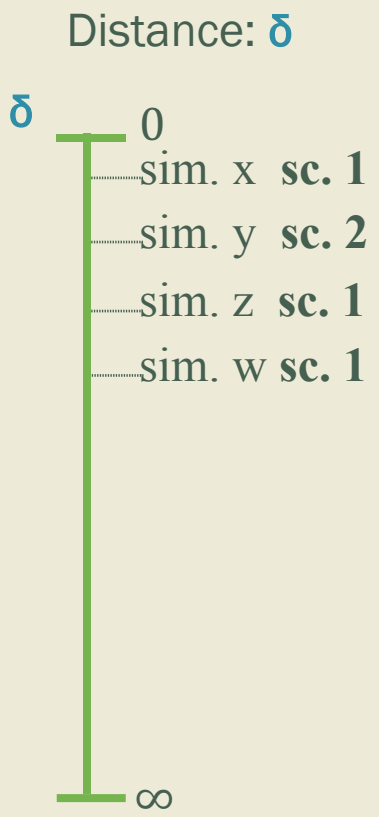
- Simulation of nucleotide matrices along each of the demographic genealogies using substitution models



Material and methods

3. Selection of the best-fit scenario

- Summary statistics: describe both observed and simulated datasets with descriptive statistics
- Euclidian distance: compute distance between each simulation and the observed dataset and rank simulations
- *Posterior* probability: determine, among the 1,000 first simulations, the proportion of simulations produced by each scenario
- Best-fit scenario: select the scenario with the highest *posterior* probability



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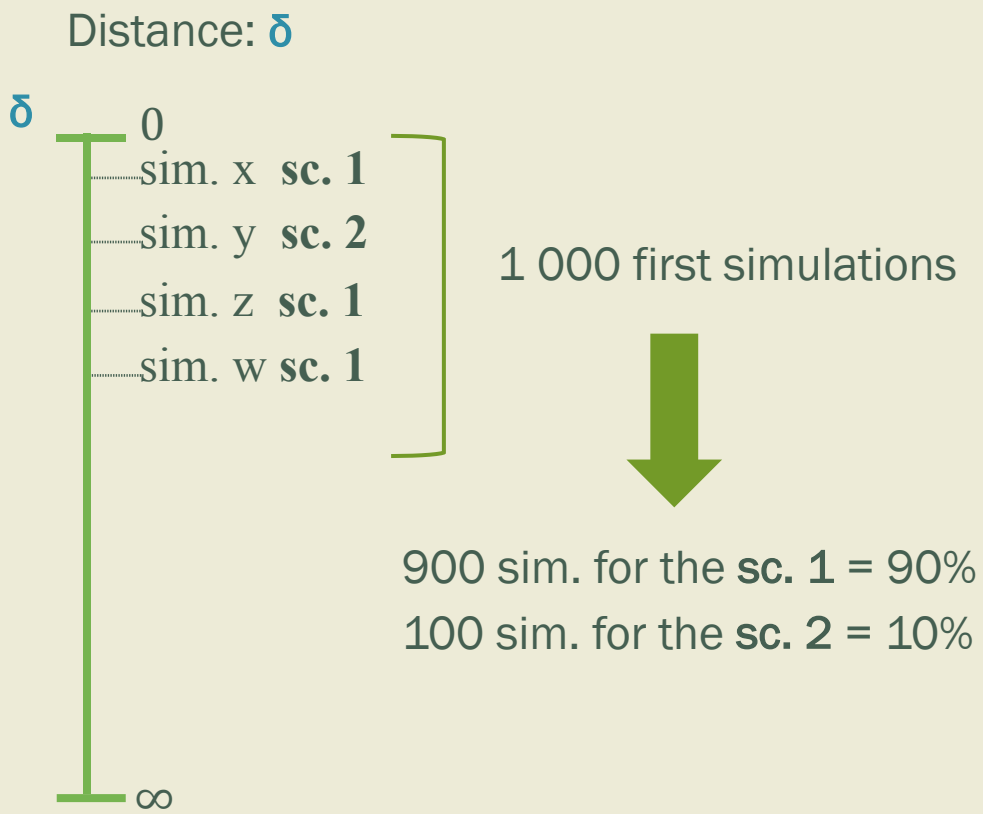

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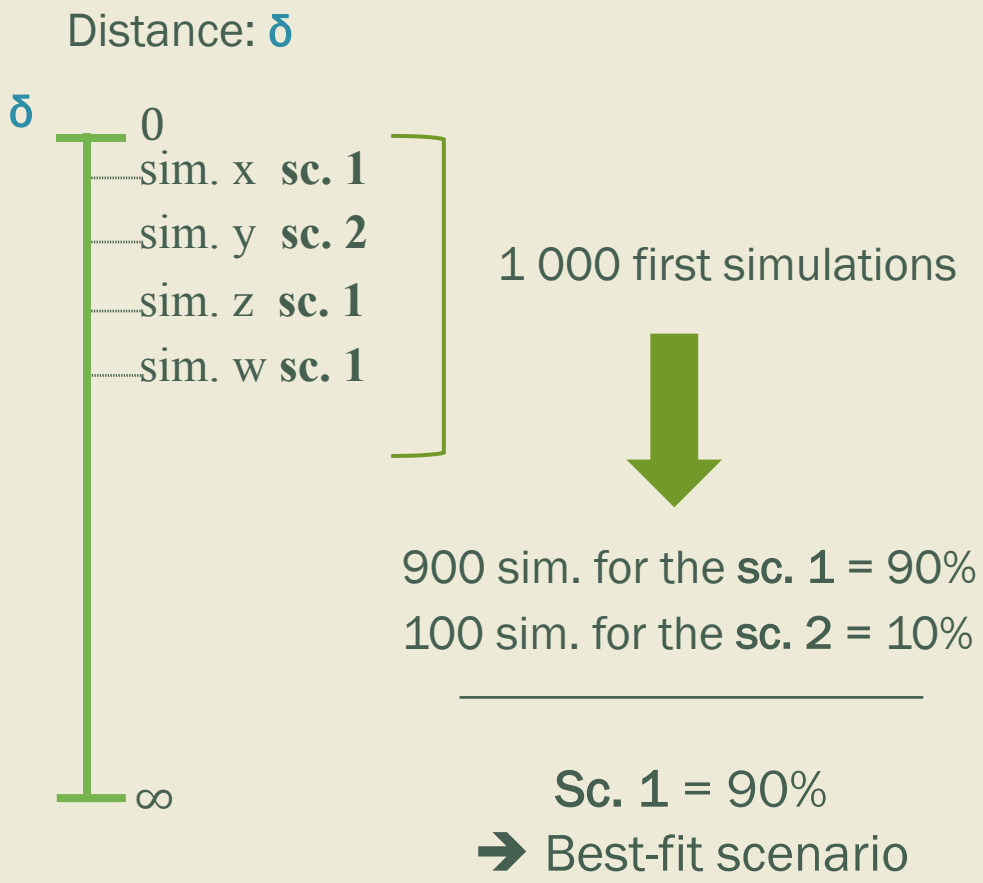
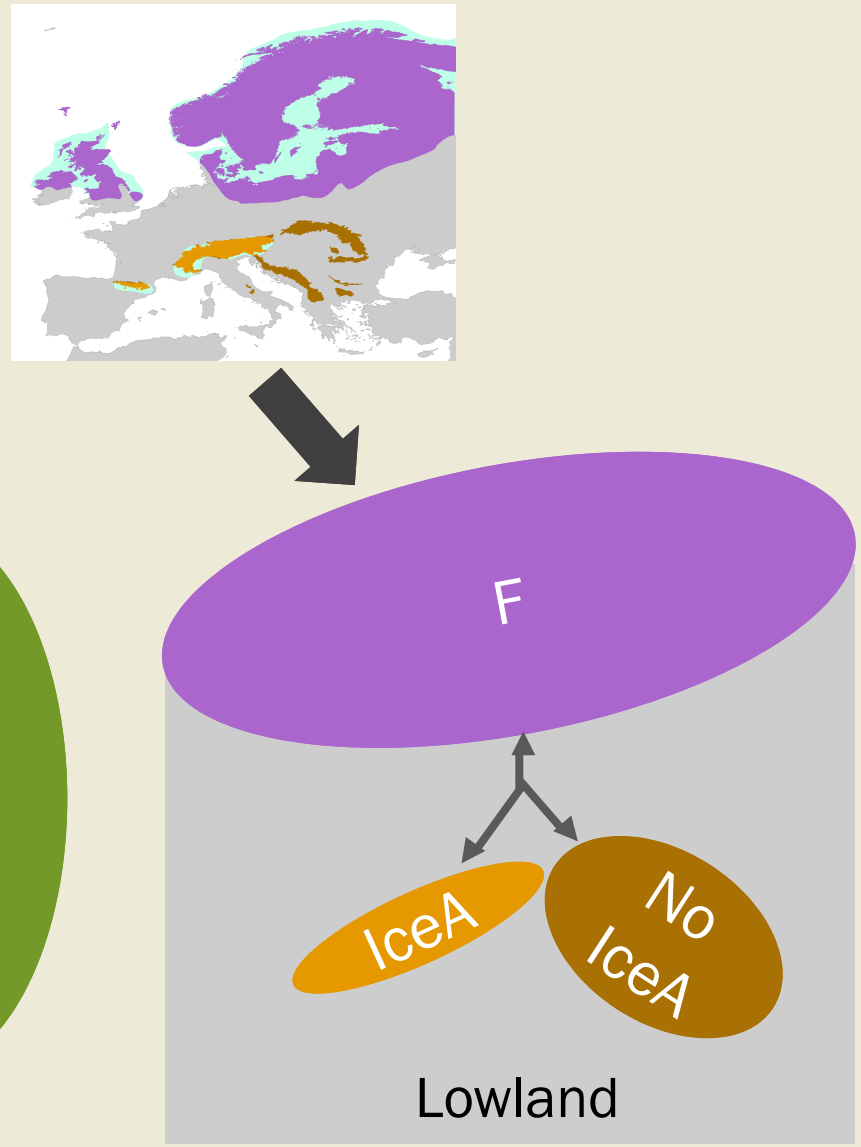


Demographic scenarios



Effective population size

= Empty

= Colonization in progress

= Full

Migrations =

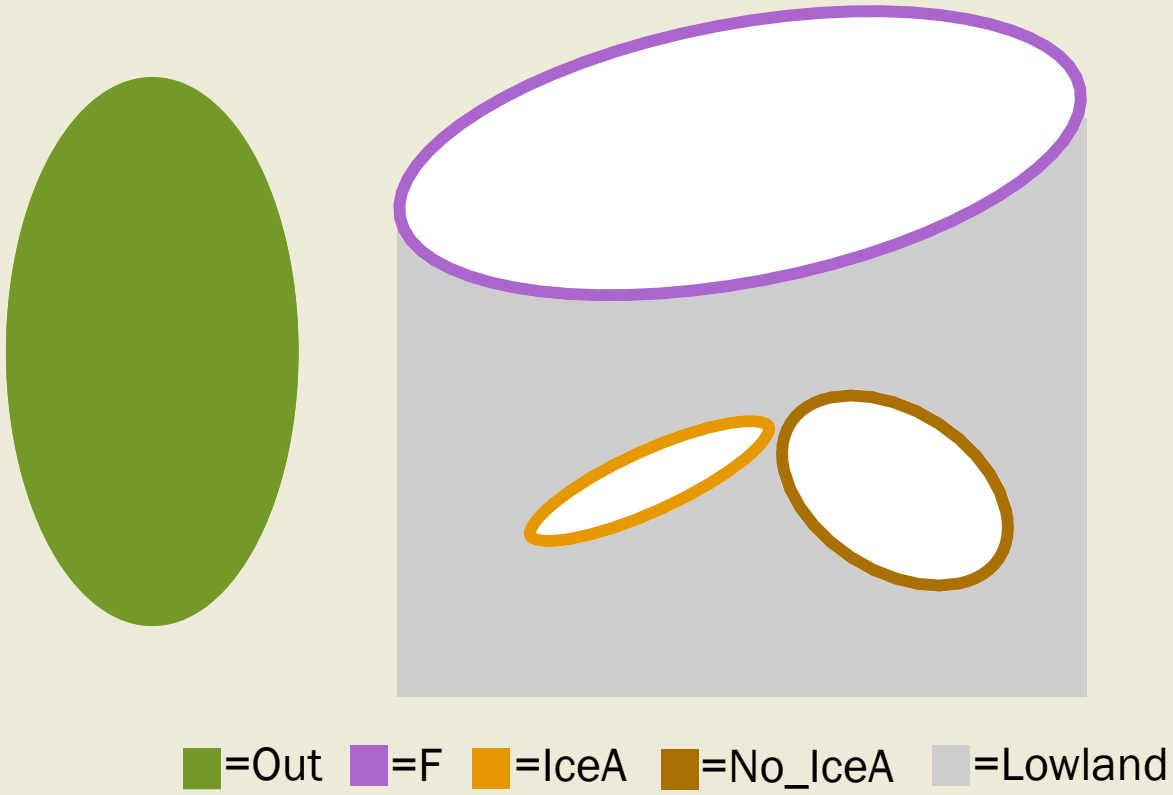
Periods

- LGM
- Onset
- Present

Demographic scenarios

Tabula rasa scenario

LGM



LGM

- No survival within the ice sheet
- Lowland areas suitable

Onset

- Recolonization from Lowland areas (outside the ice sheet)

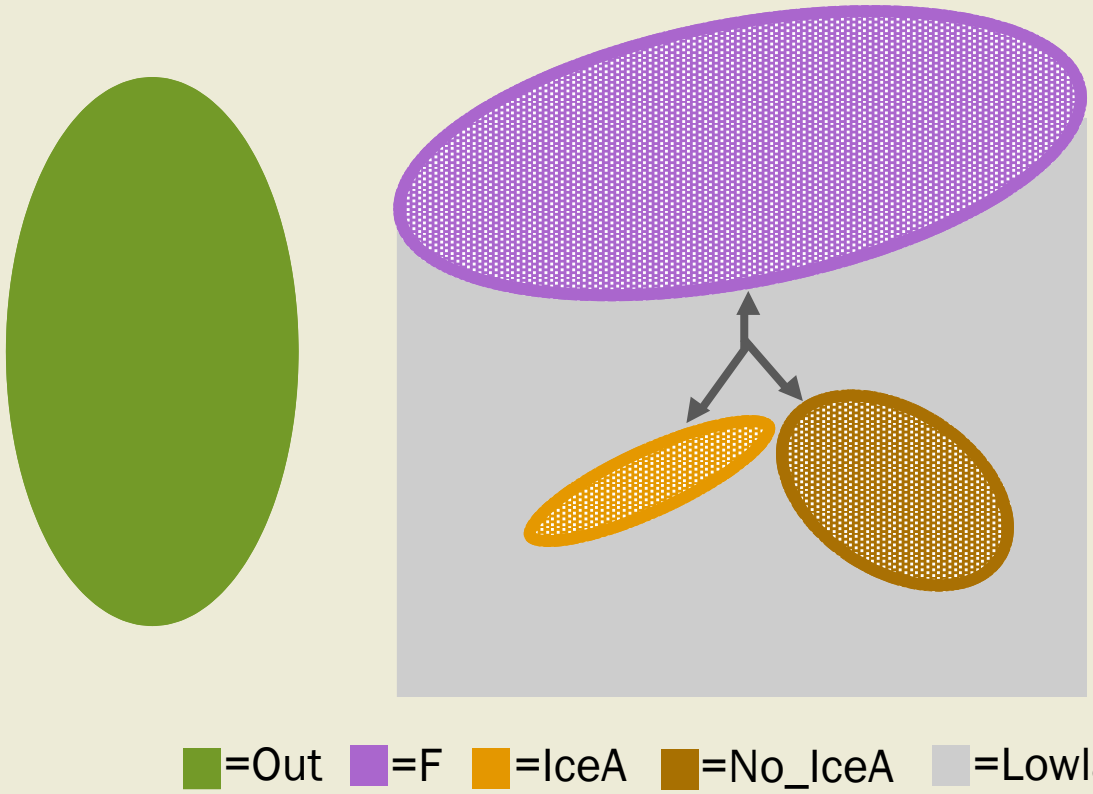
Present

- Lowland area no longer suitable
  - Too hot and dry
  - Too much competition

Demographic scenarios

Tabula rasa scenario

Onset



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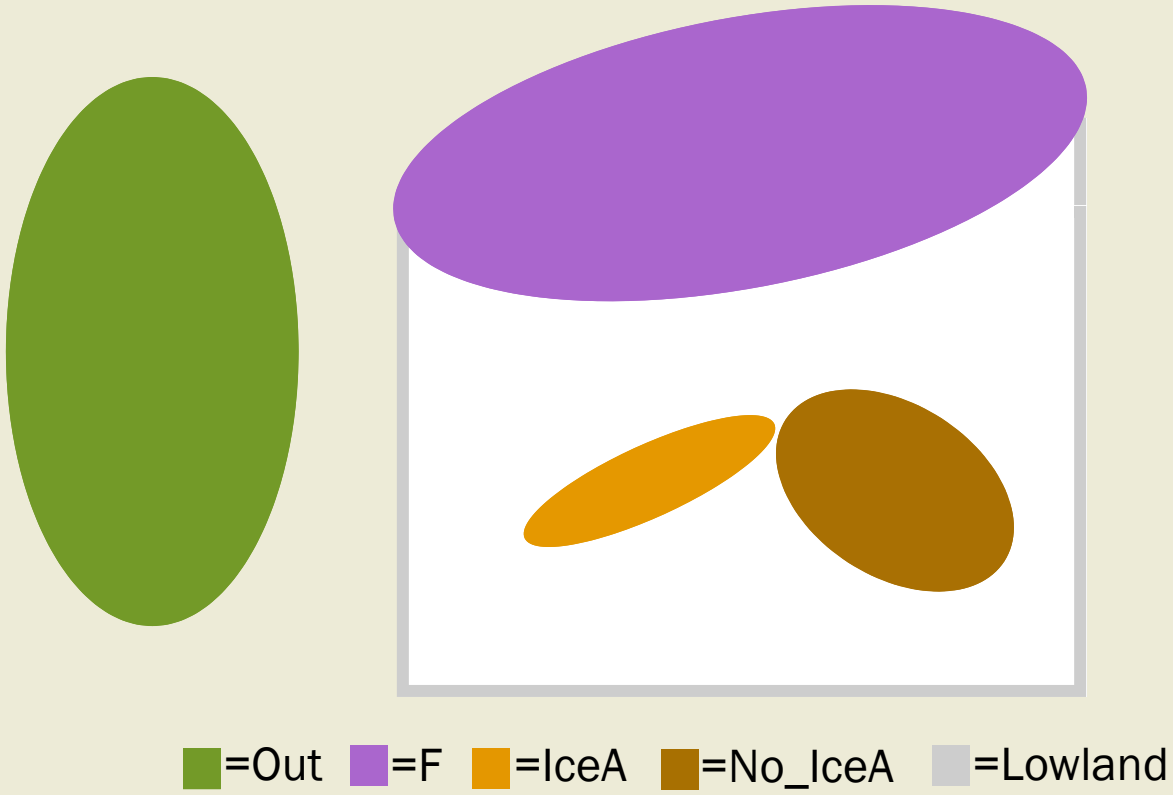

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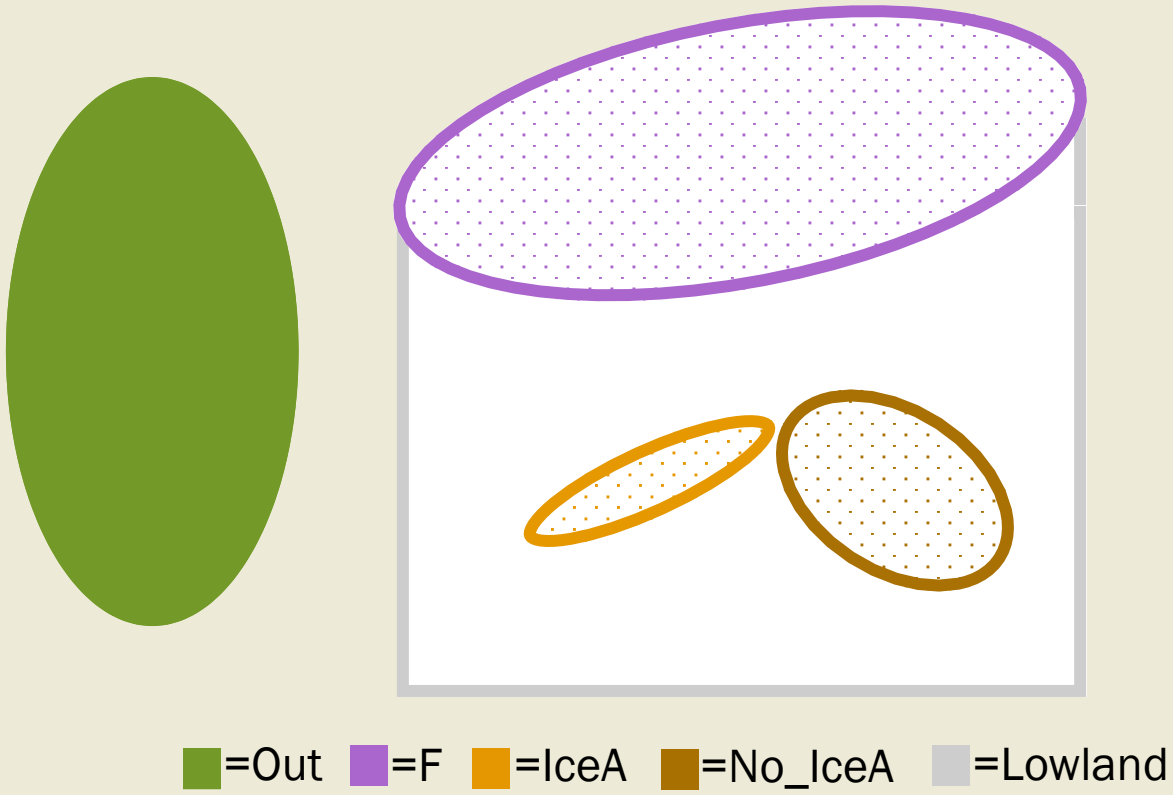
Nunatak scenario

LGM



LGM

- Lowland area not suitable
  - Too dry
- *In-situ* survival in micro-*refugia* within the ice sheet

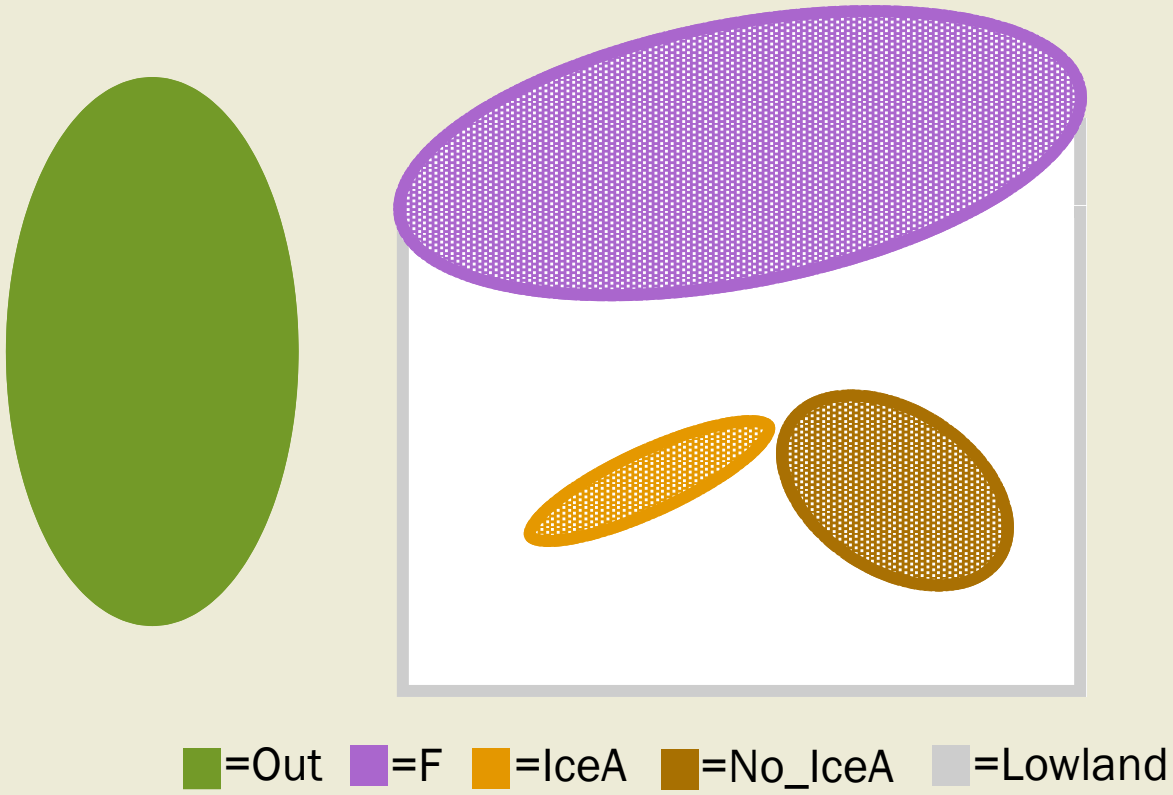
Onset

- Populations expansion from those *refugia*

Demographic scenarios

Nunatak scenario

Onset



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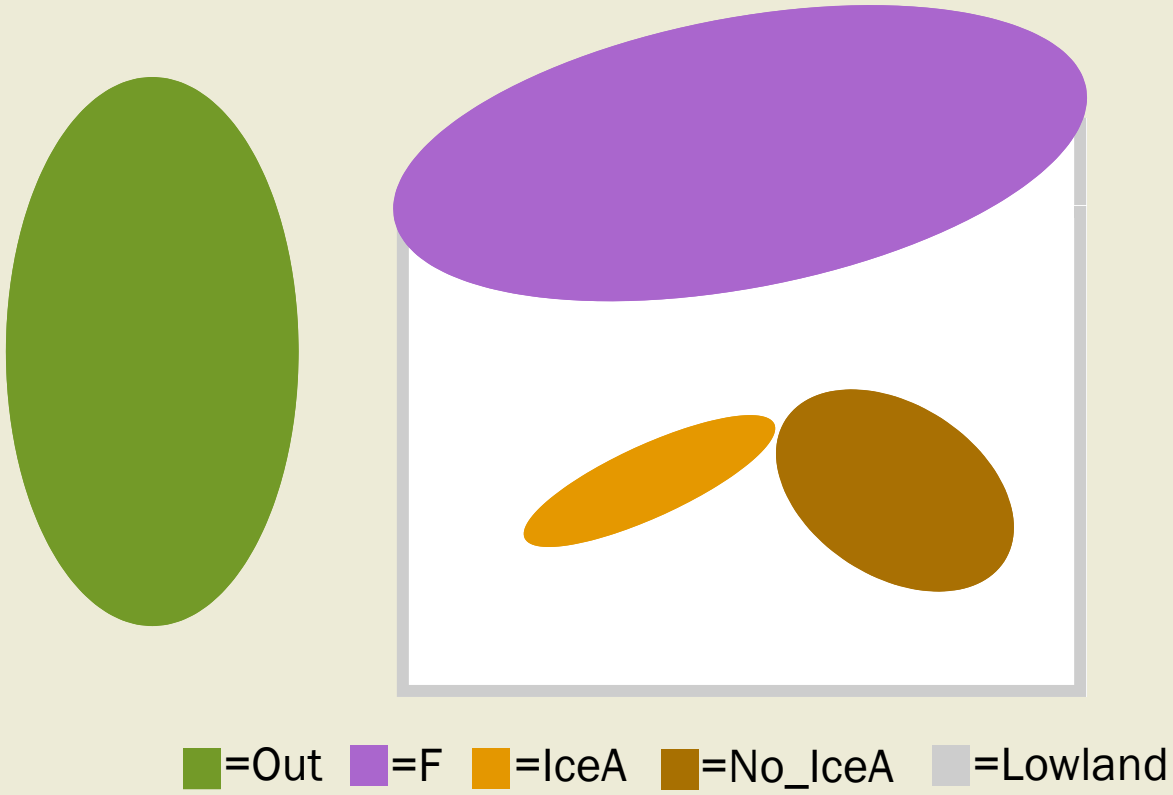

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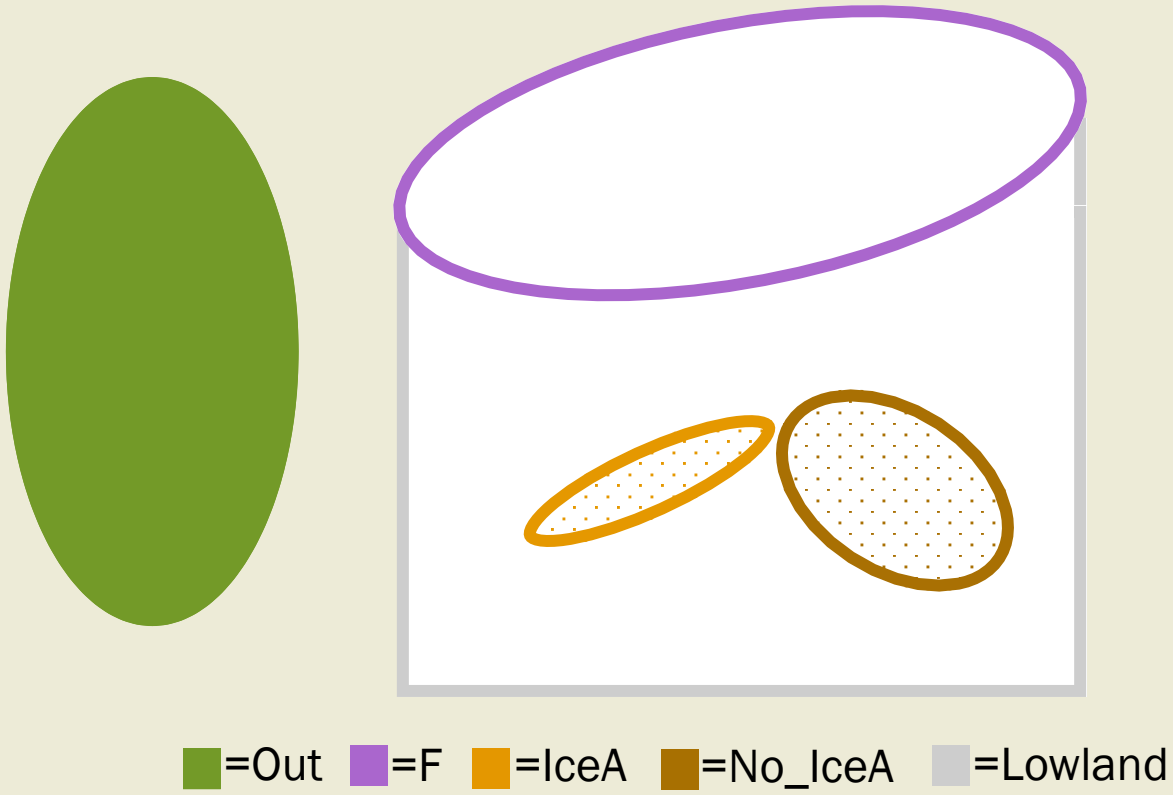
Demographic scenarios

Alpine *Nunatak* scenario

LGM



LGM

- Lowland area not suitable
  - Too dry
- Micro-*refugia* in southern Alpine regions only

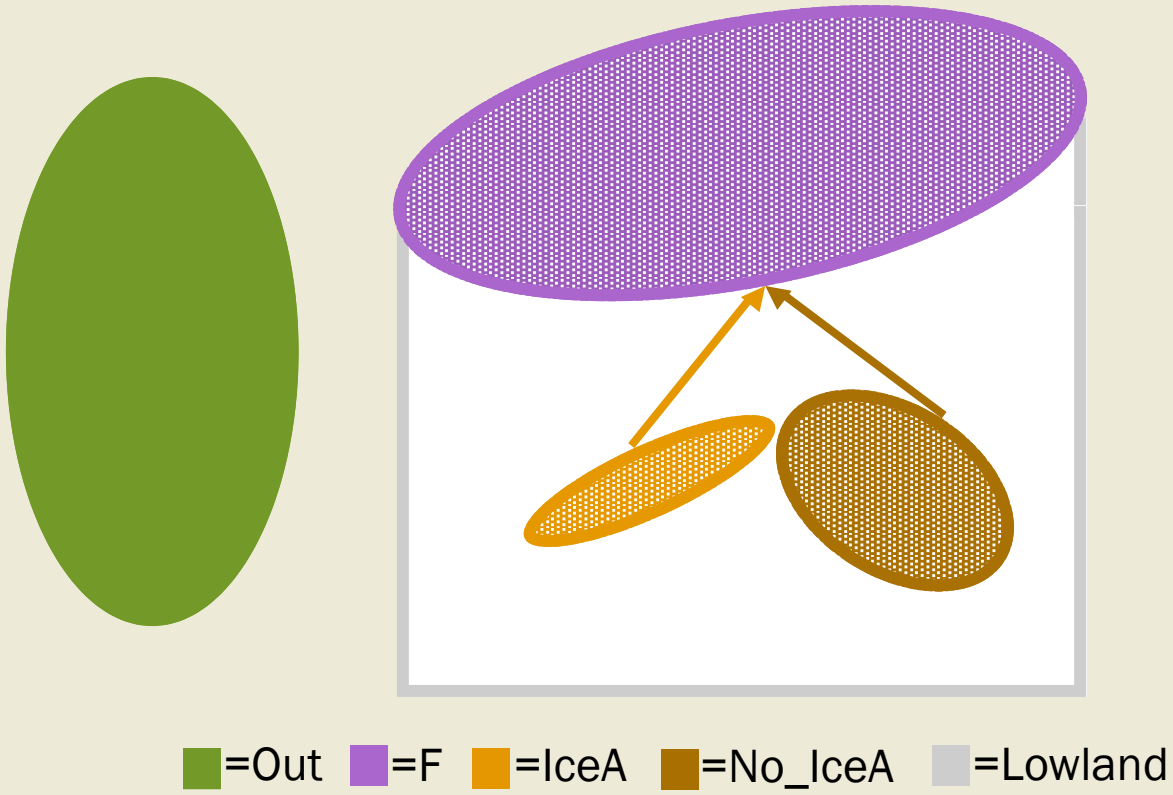
Onset

- Recolonization of Fennoscandia from those *refugia*
- Populations expansion

Demographic scenarios

Alpine *Nunatak* scenario

Onset



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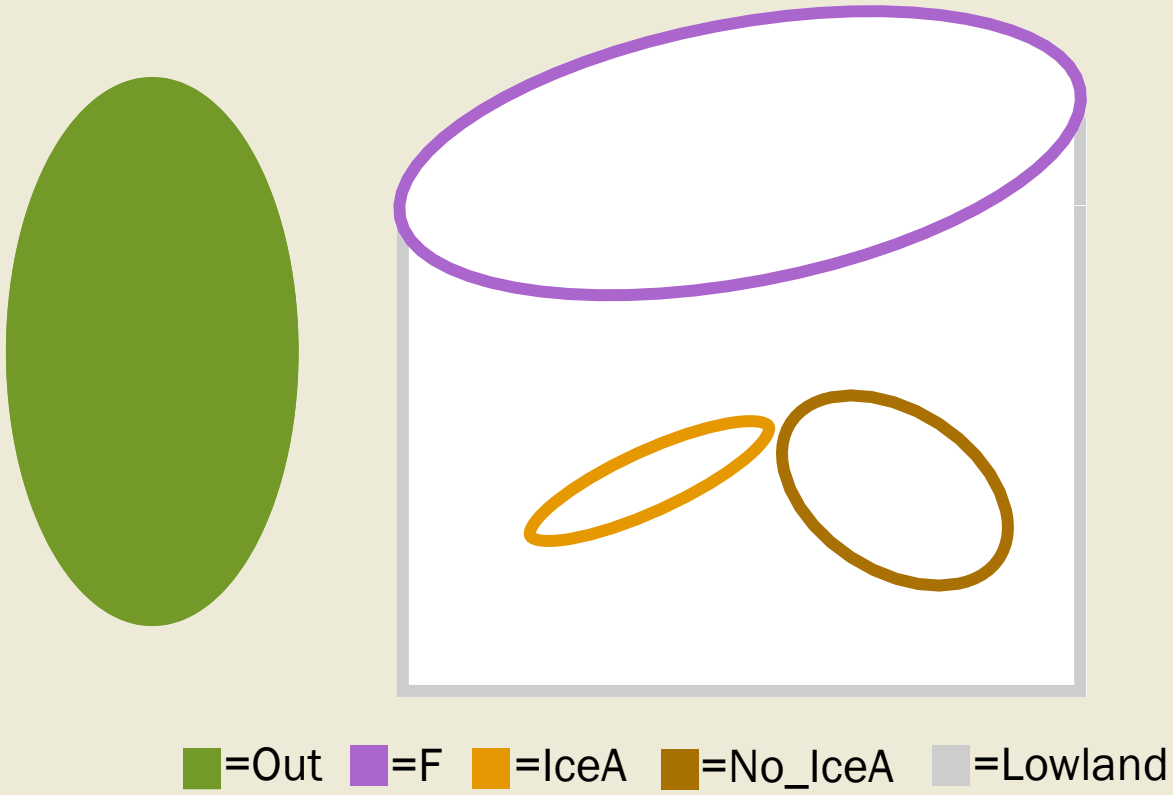
Demographic scenarios

Out-of-Europe scenario

LGM



LGM

- No survival within the ice sheet
- Lowland area not suitable either
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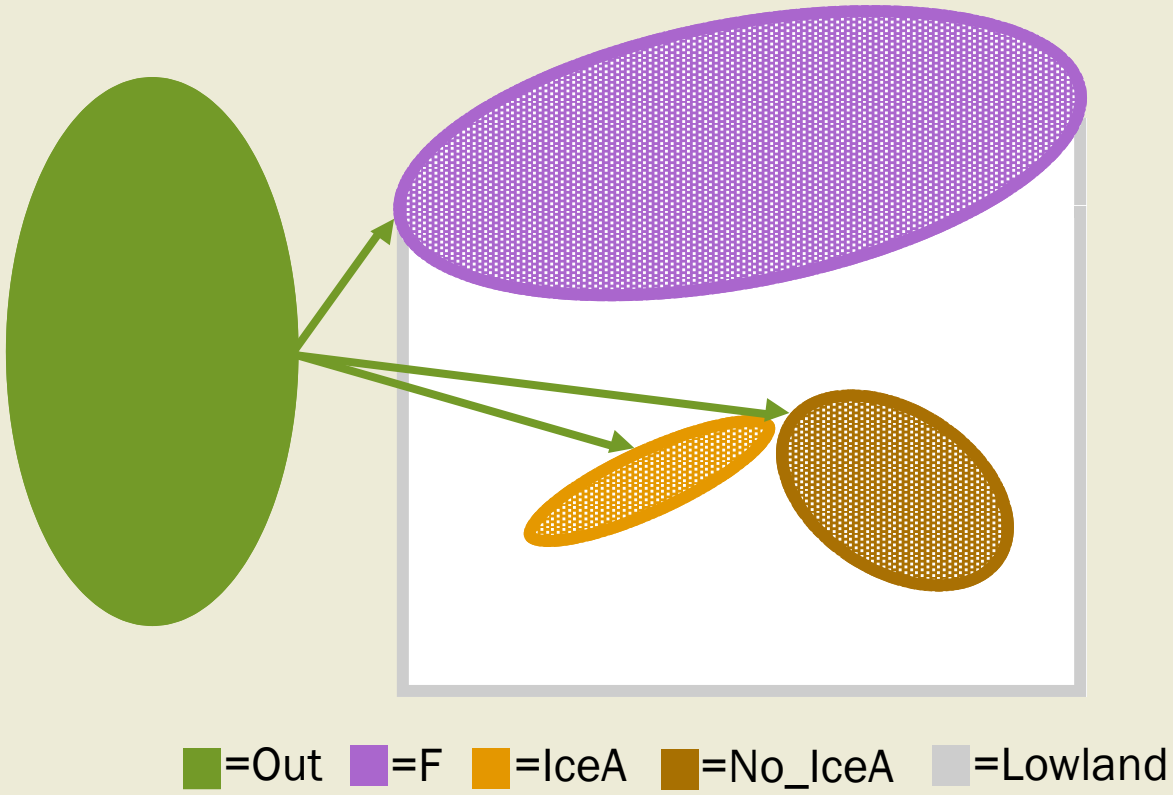
Onset

- Recolonization of Arctic-Alpine regions from out-of-Europe populations

Demographic scenarios

Out-of-Europe scenario

Onset



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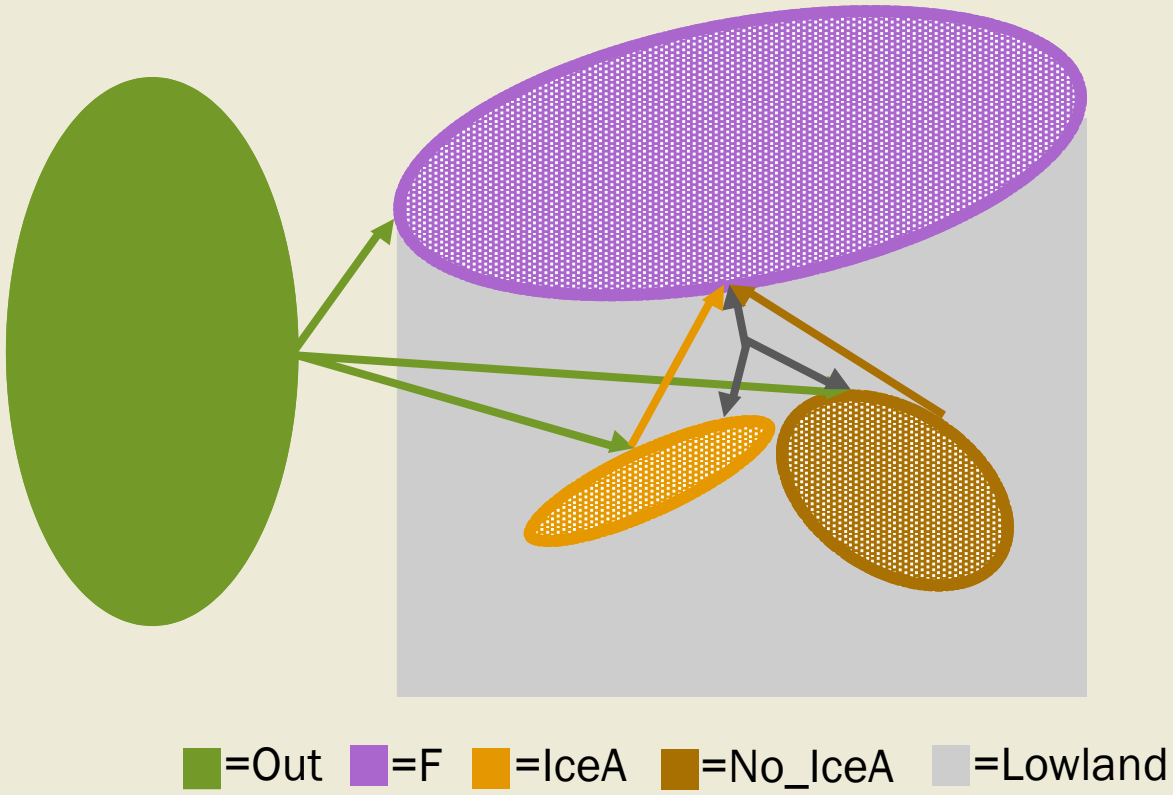
Demographic scenarios

Composite scenario a

Onset



LGM

- Lowland areas suitable
- *In-situ* survival in micro-*refugia* within the ice sheet

Onset

- Migration rates from both Lowland and Out-of-Europe areas to Arctic-Alpine regions
- Migration rates from Alpine regions to Fennoscandia

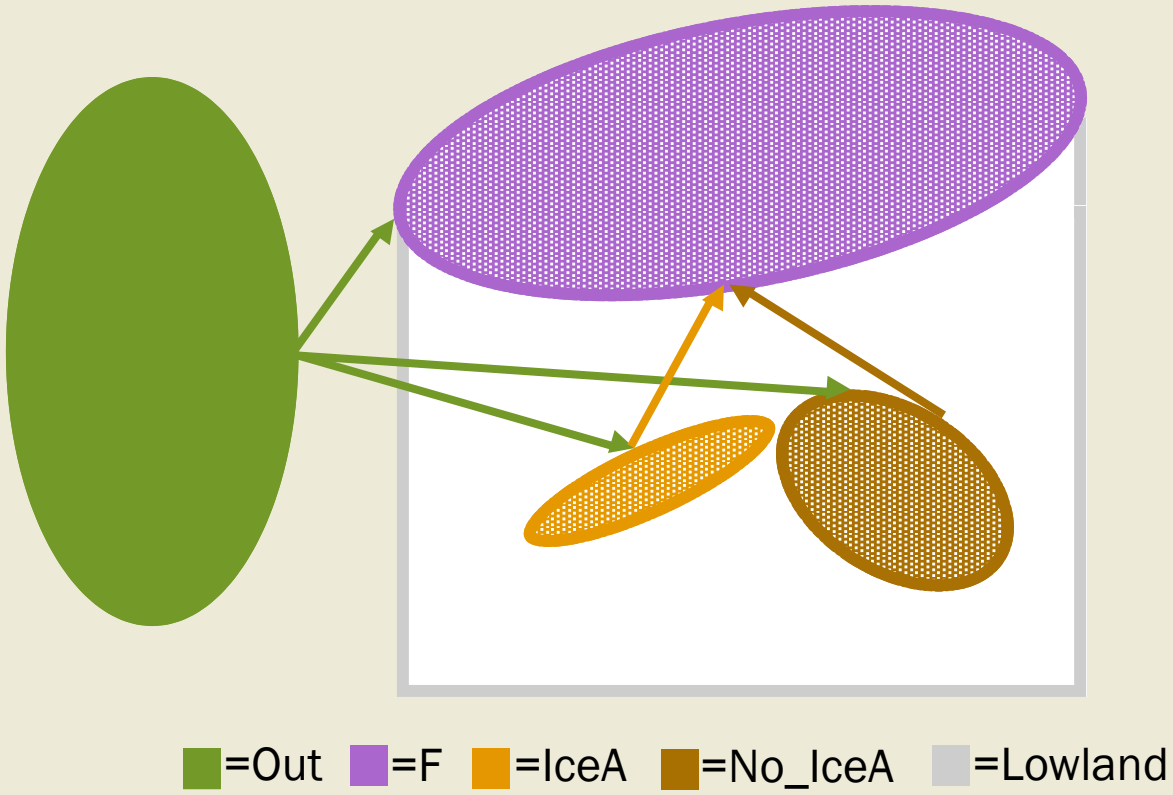
Present

- Lowland area no longer suitable
  - Too hot
  - Too much competition

Demographic scenarios

Composite scenario b

Onset



LGM

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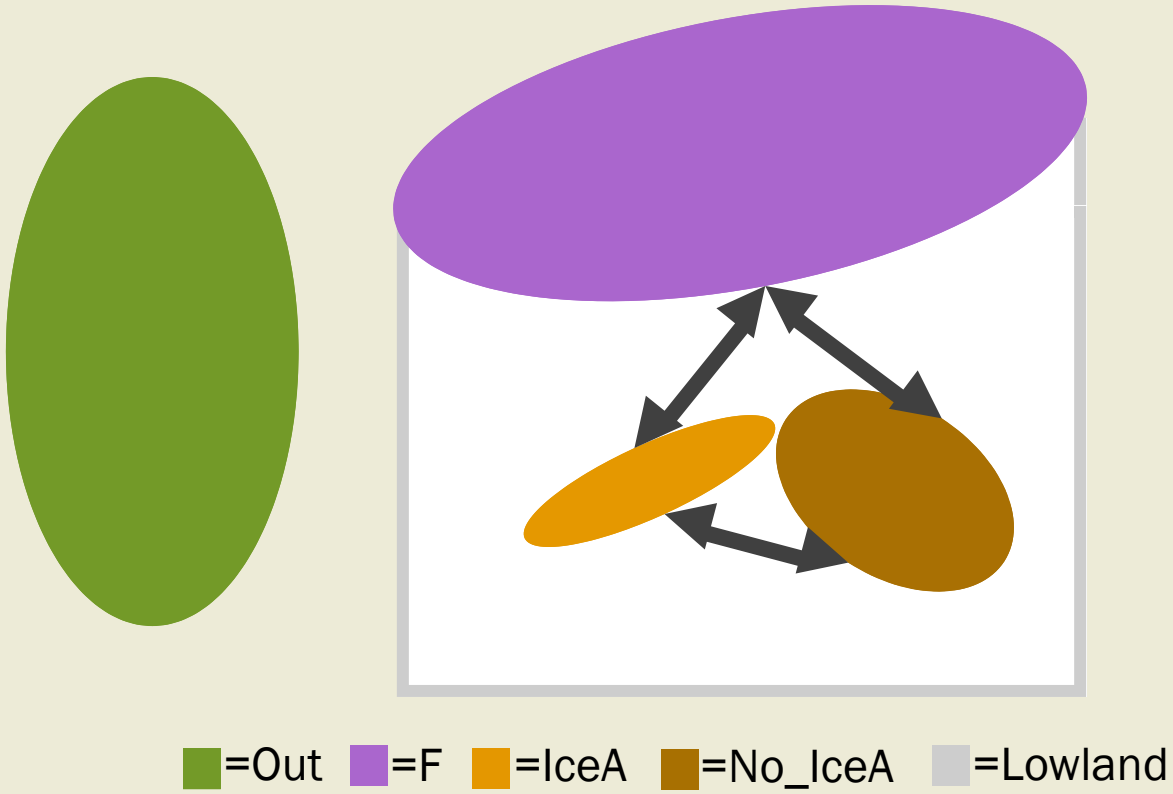
Onset

- Migration rates from Out-of-Europe areas to Arctic-Alpine regions
- Migration rates from Alpine regions to Fennoscandia

Demographic scenarios

Nul hypothesis (H0): Test for phylogeographic signal

Present



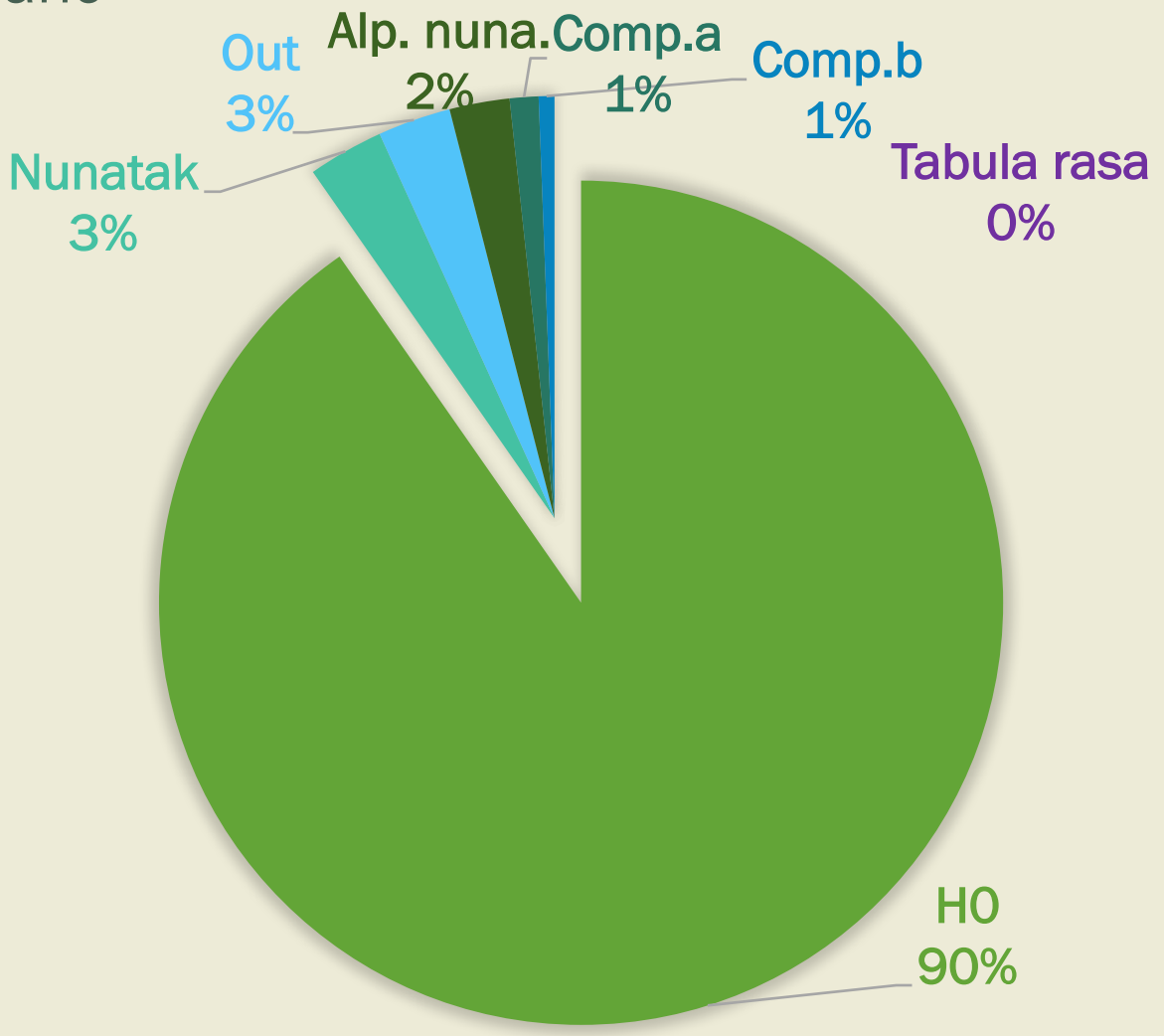
Present

- Whatever happened before, post-glacial migration rates within Europe erase any historical signal

Results and discussion

Posterior probability of each scenario

- *Timmia bavarica*



Best-Fit scenario : H0

⇒ Nul hypothesis!

⇒ No phylogeographic signal in the data!

Tabula rasa : 0%

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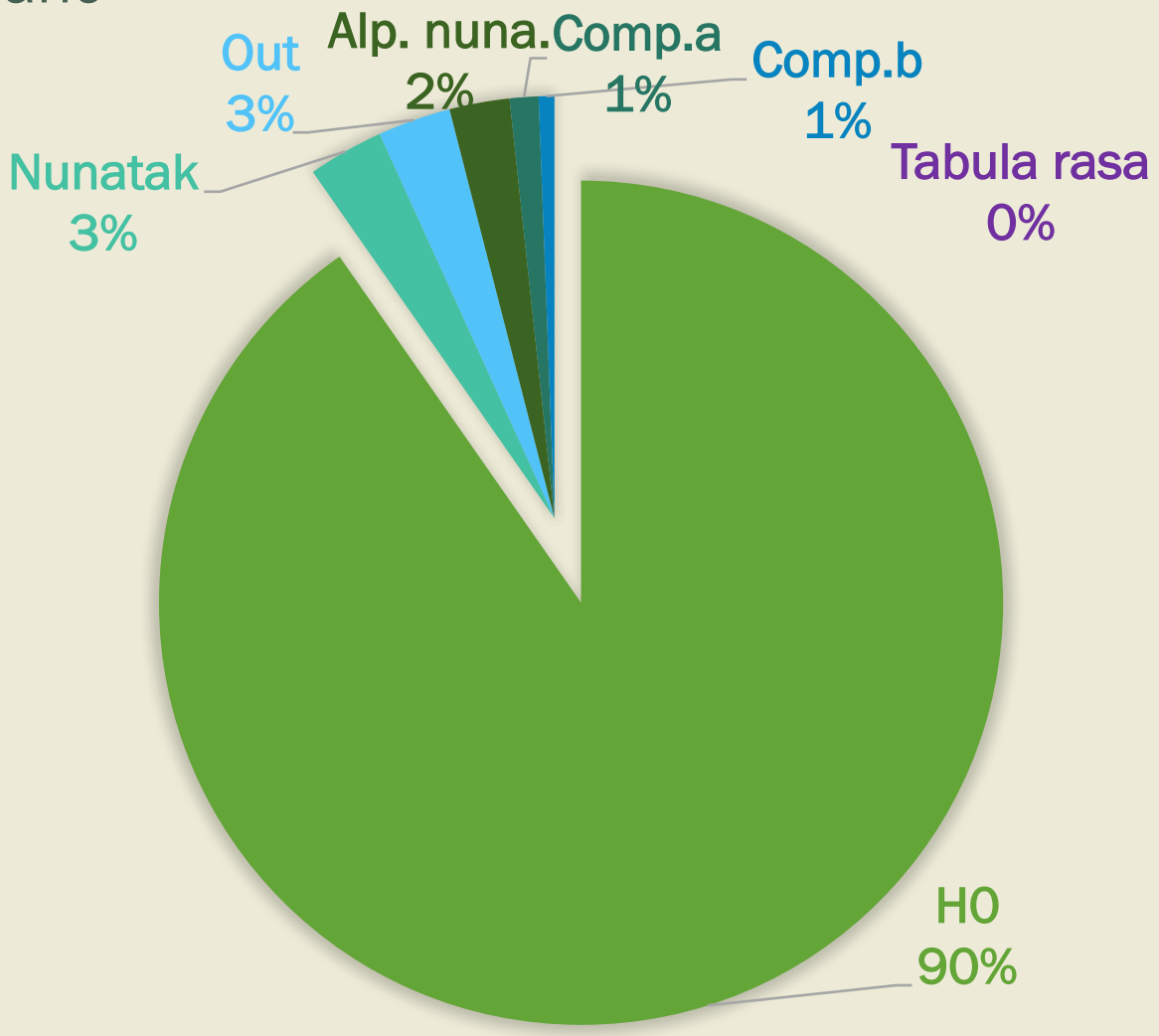

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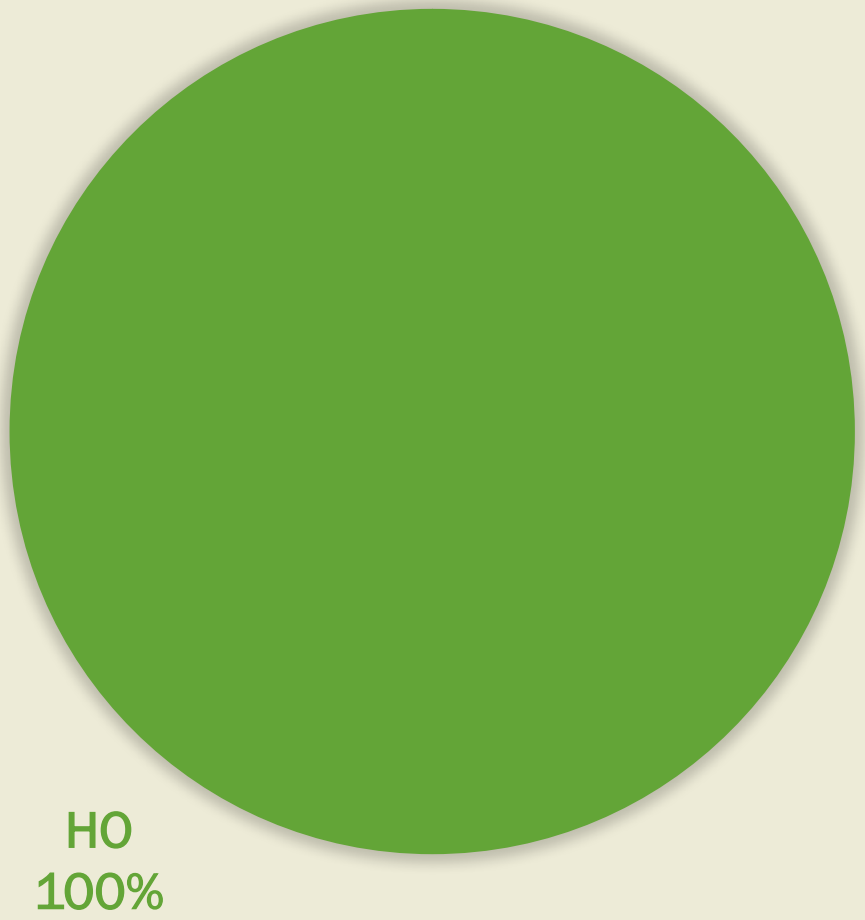

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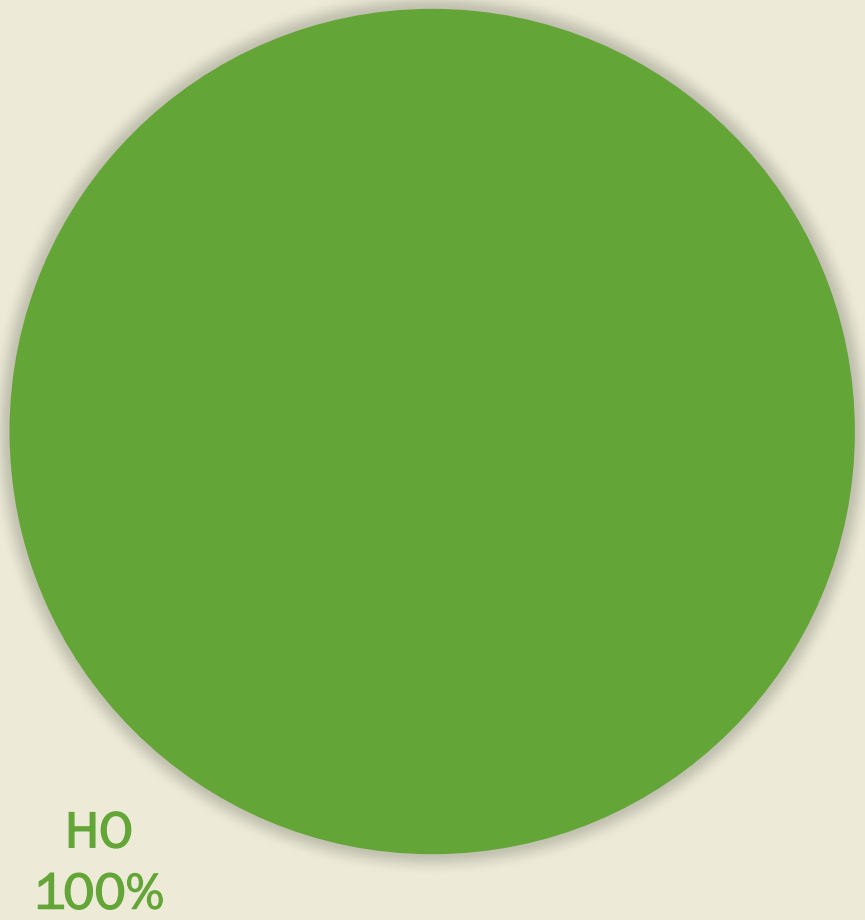

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- PRELIMINARY RESULTS

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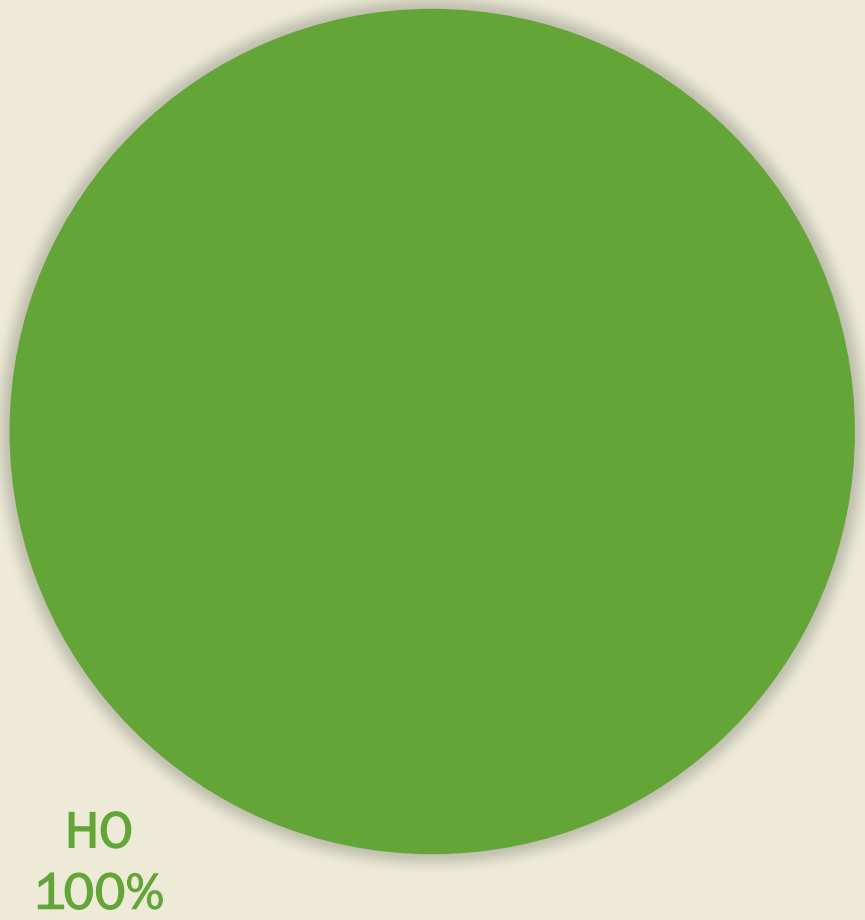

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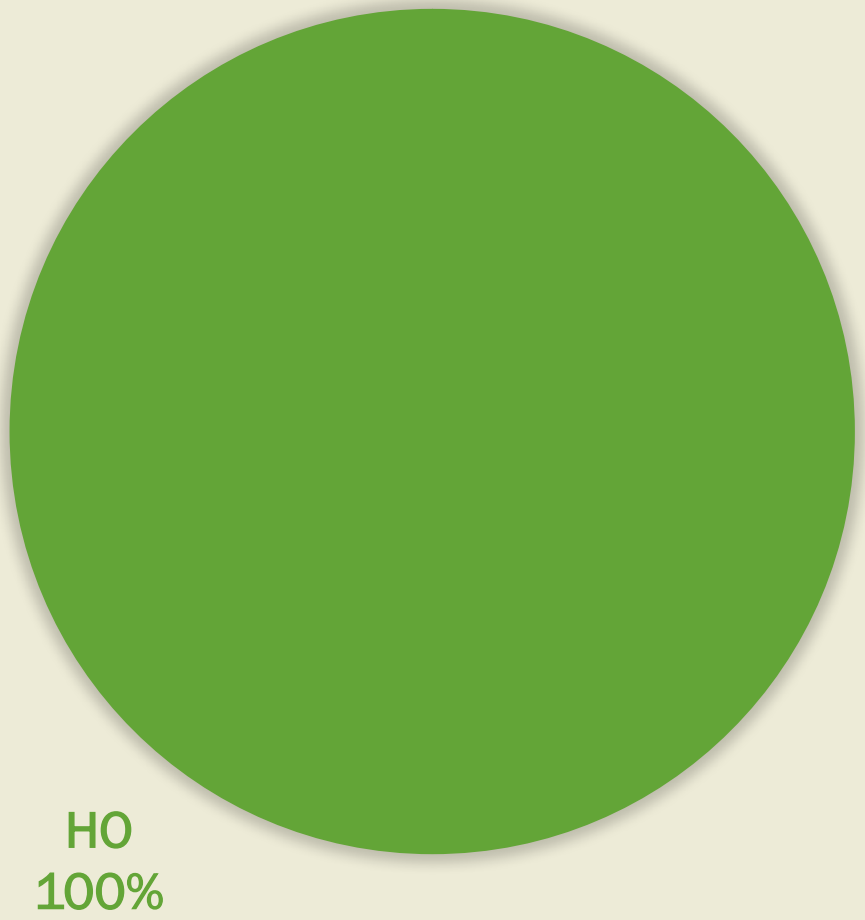

Results and discussion

H0 is the best-fit scenario!

- Unexpected result
- Actual migration rates within Europe erase any trace of historical signal

⇒ Highlights the high dispersal capacities of bryophytes

Consequence

- Impossible to retrace the biogeographic history of the Arctic-Alpine mosses in Europe…

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Conclusion and perspectives

Arctic-Alpine populations highly endangered

- In the context of climate change
- Especially Alpine populations
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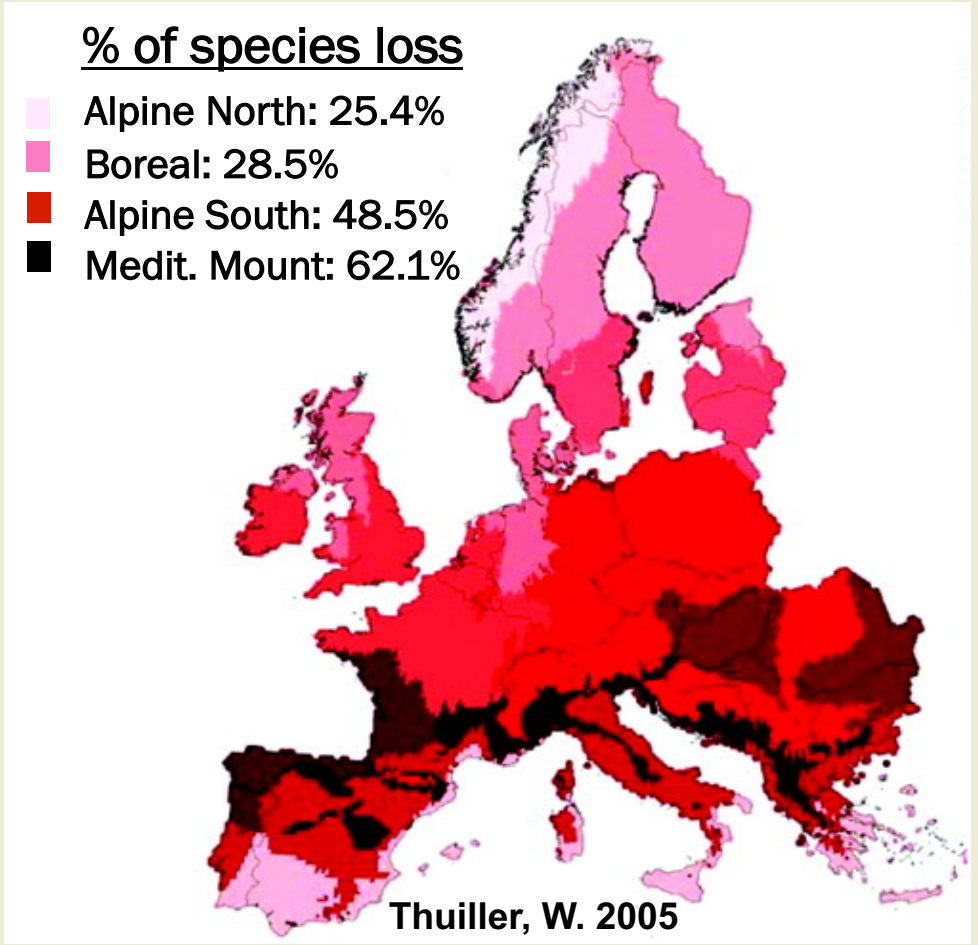
  - By 2080, 48.5% of the Alpine plant species will be lost against 28.5% for the Arctic ones



BUT : Great news!

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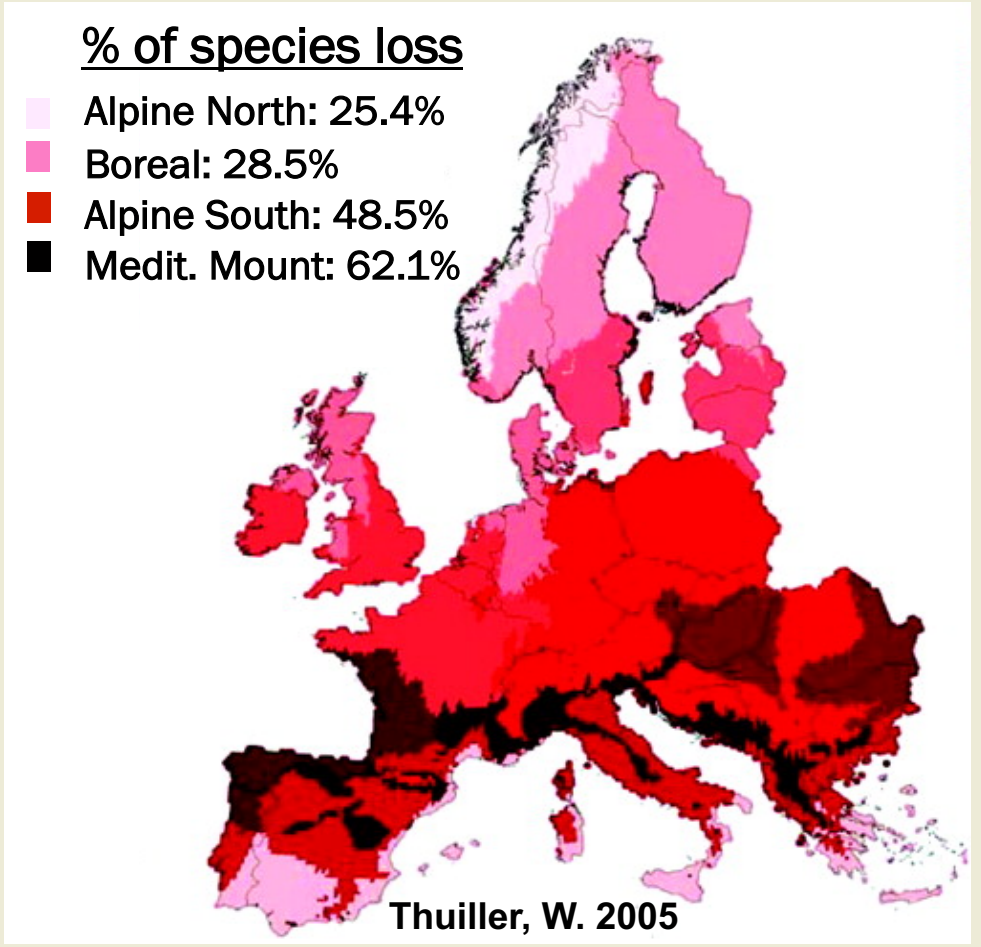

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THANK YOU FOR YOUR ATTENTION!
Questions?