Phenology and adaptive landscapes in future climate:

what consequences for the maladaptation of tree species?

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PHENO 2022

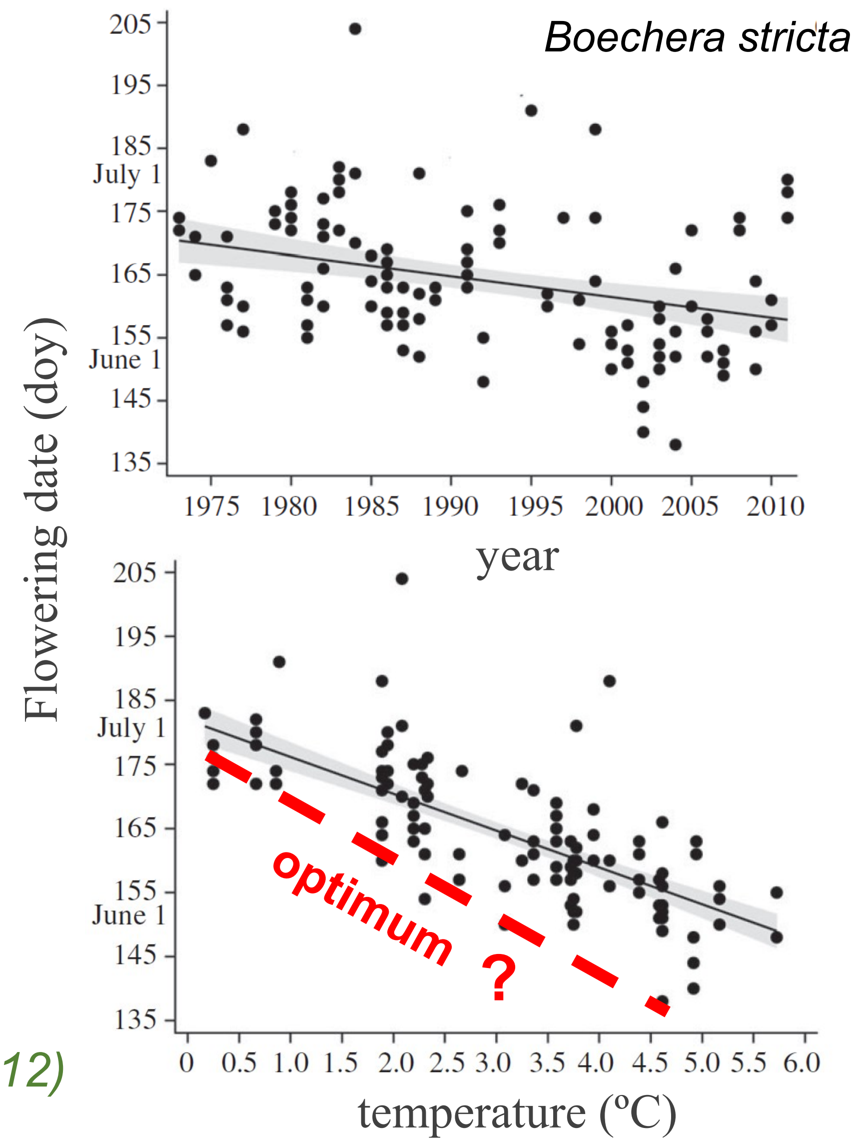
Context

Advancement of spring phenology in many species

→ **plastic response of phenology to spring temperatures**

Does trait variation allow tracking the variation in optimum phenotypic traits?

Anderson et al. Proc R Soc. B (2012)

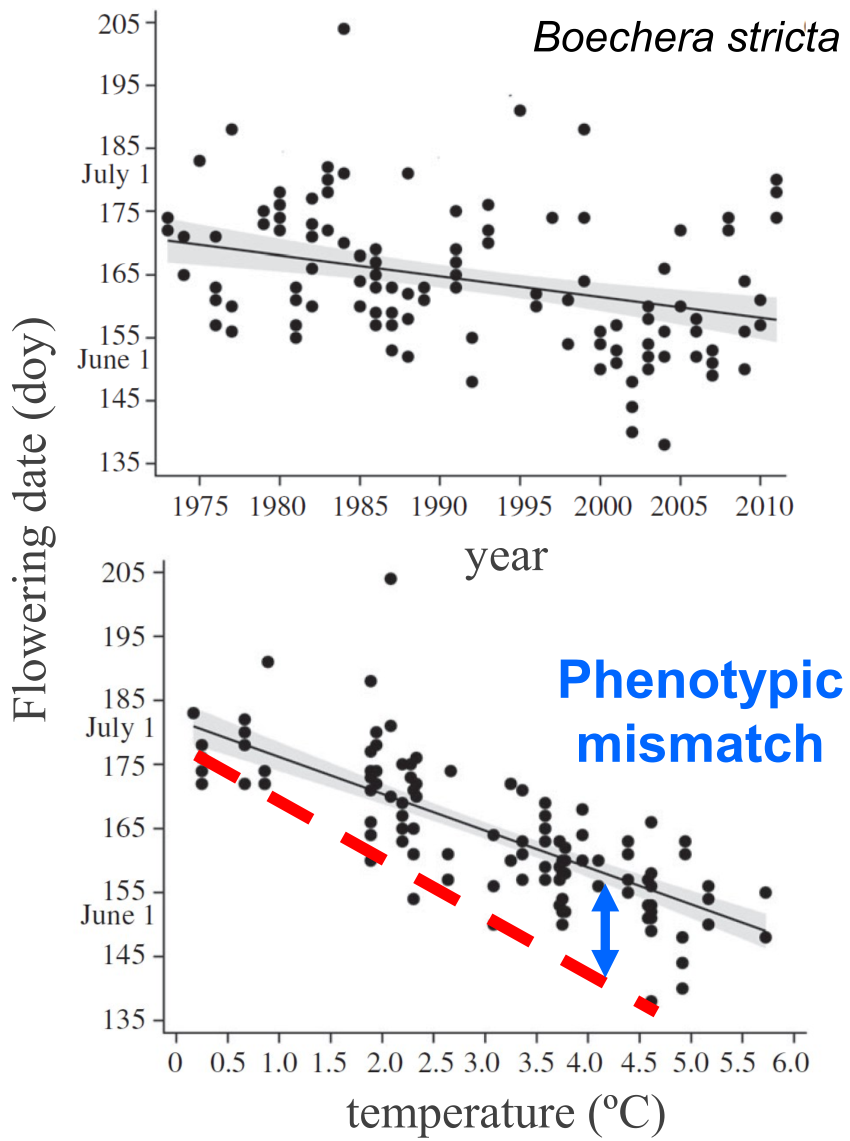


Context

Concern that mismatch increases with CC

→ **increasing maladaptation?**

→ **extinction risk?**



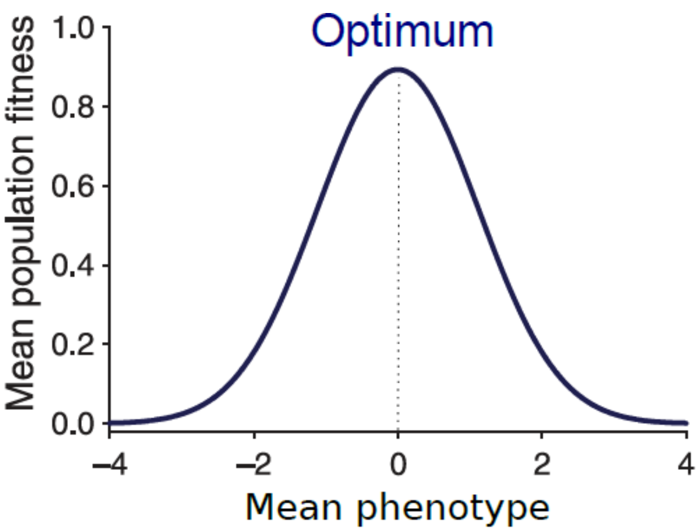
Context

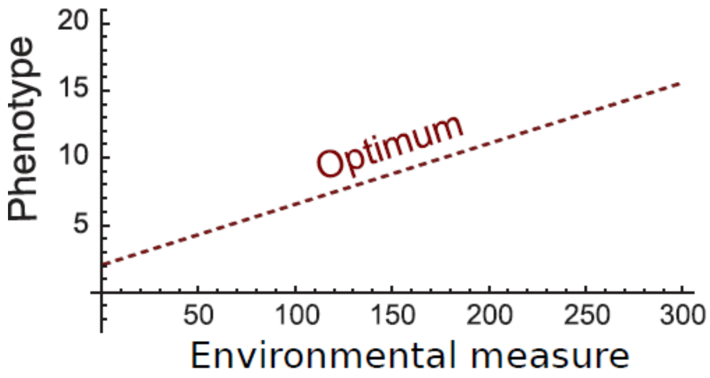
Models of phenotypic adaptation

- stabilizing selection around some optimal phenotype

- environmental change only affects the optimum

Changes in the optimum with environmental variation are often difficult to estimate, especially in long-lived plant species





A mechanistic modelling approach

a complementary approach to empirical estimates

<u>PHENOFIT model</u>

inputs

Local climate + Parameter set

Phenology models
budburst,
flowering, fruit maturation,
leaf senescence

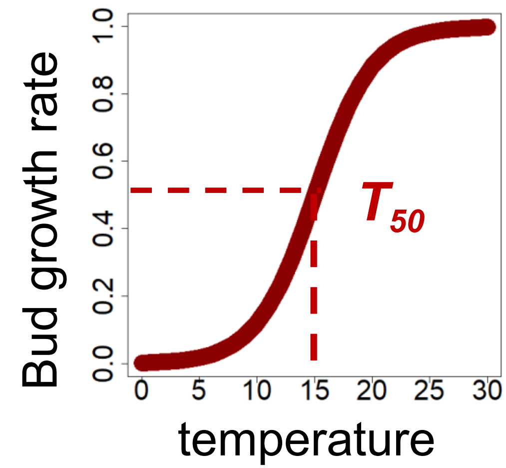
Stress resistance
models
frost & drought

Phenological dates
e.g. **budburst dates**

outputs

Reproductive success

output

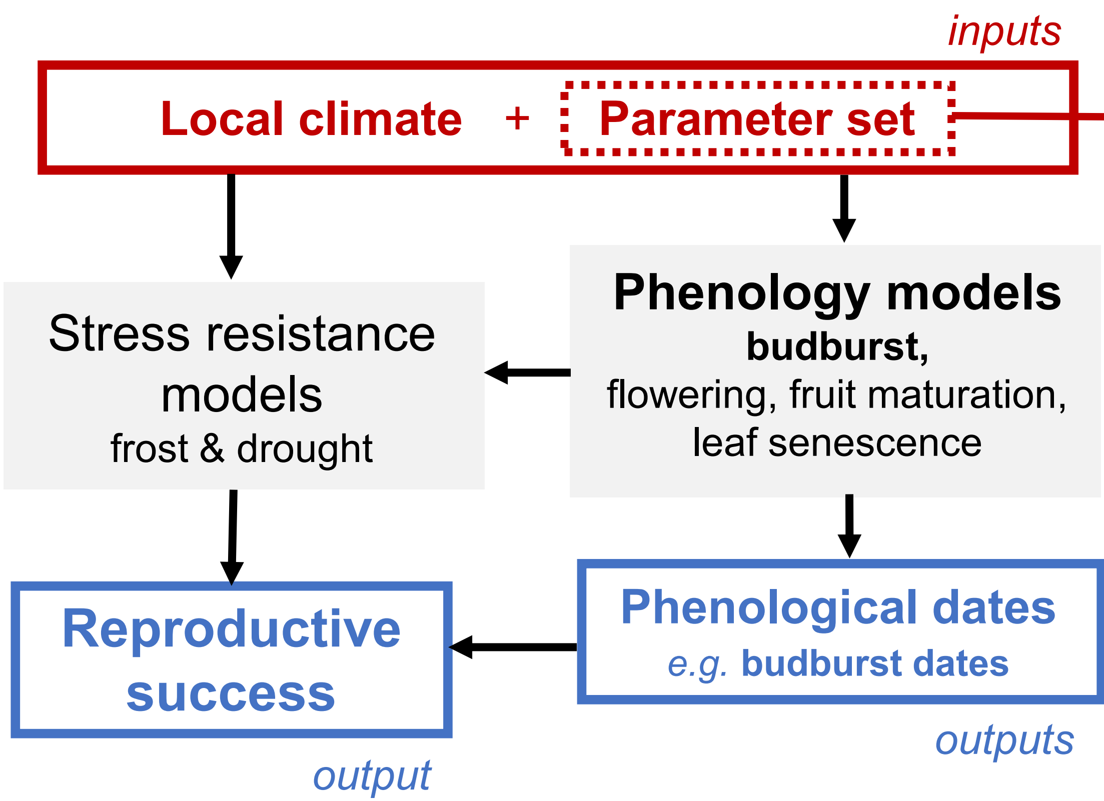


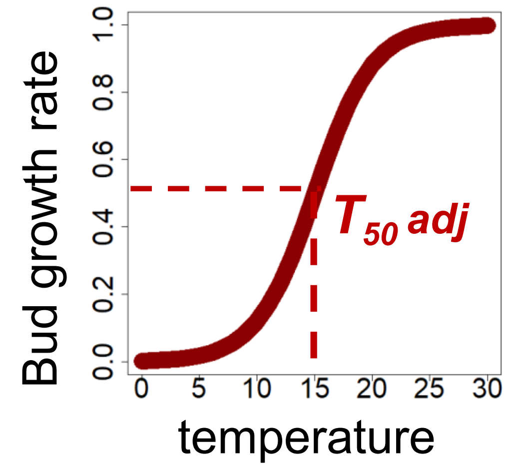
One parameter set per species

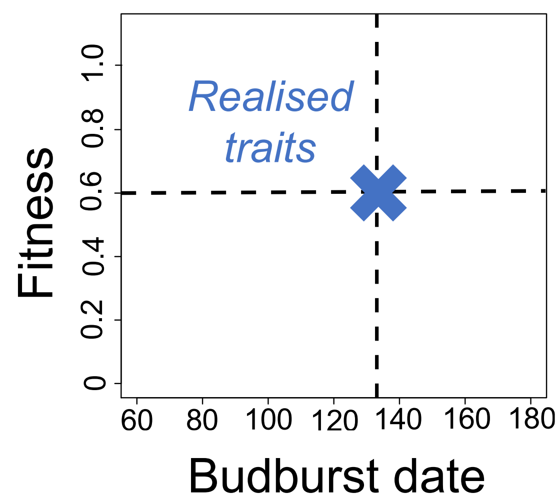
Chuine and Beaubien Ecol Lett. (2001)

A mechanistic modelling approach

Step (1) : use calibrated reaction norm to predict a local budburst date

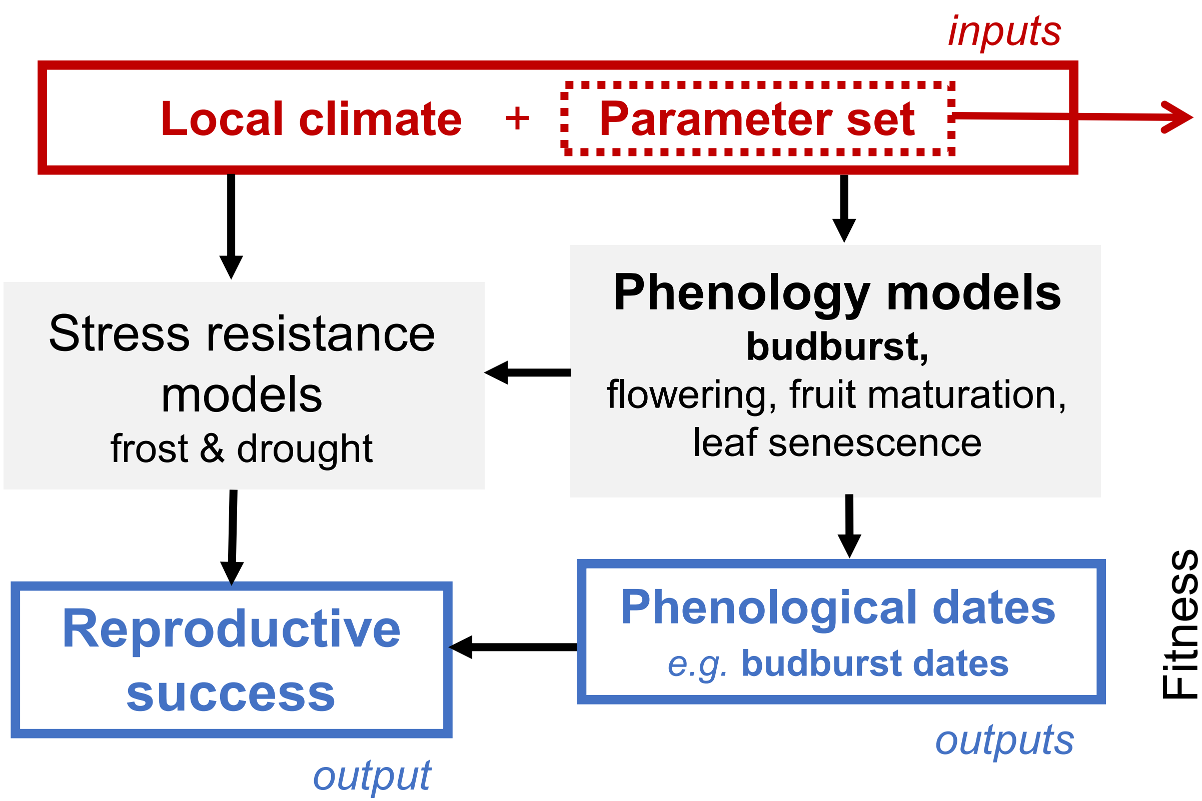


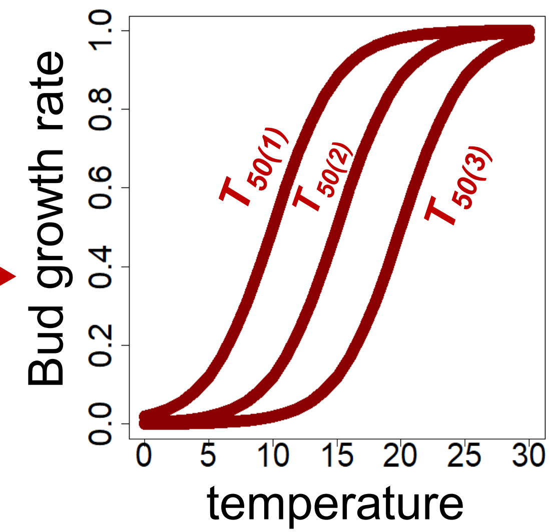


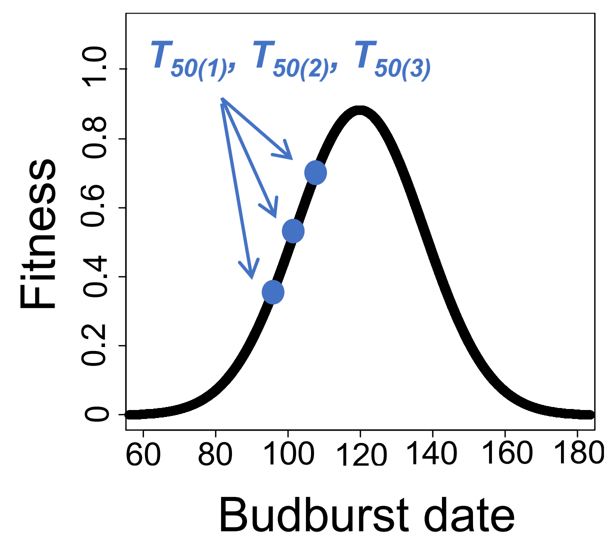


A mechanistic modelling approach

Step (2) : sensitivity analysis to predict fitness landscape

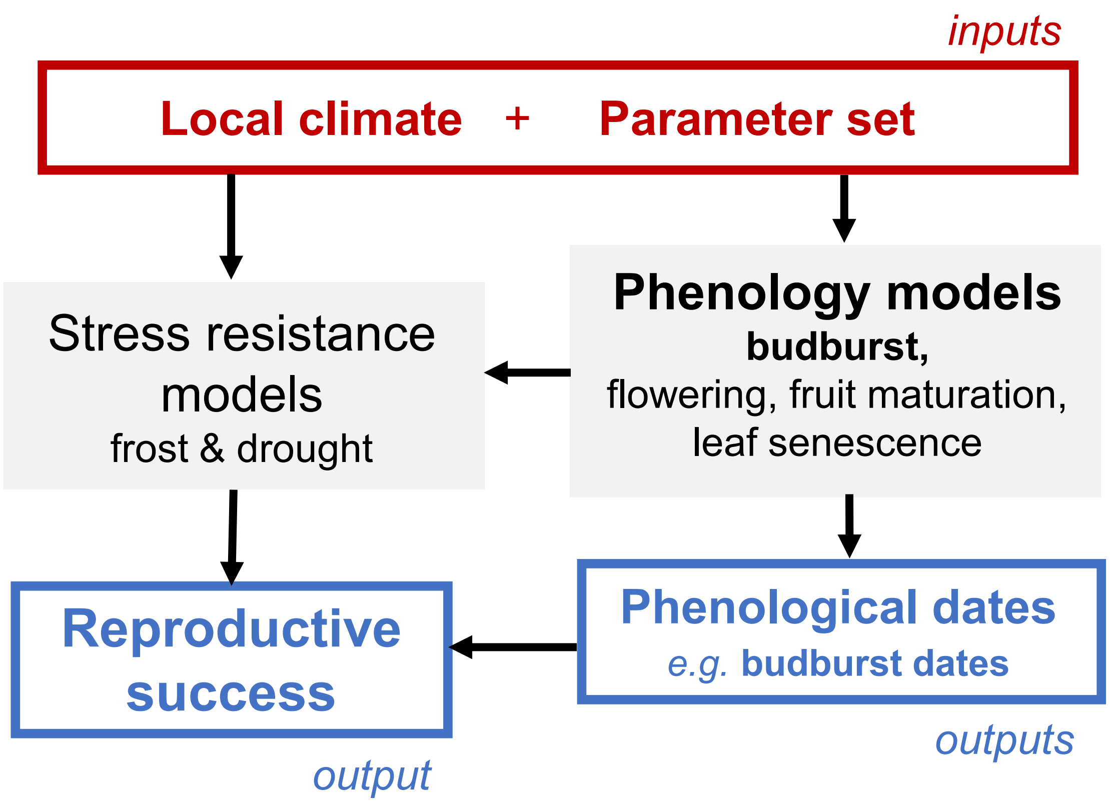


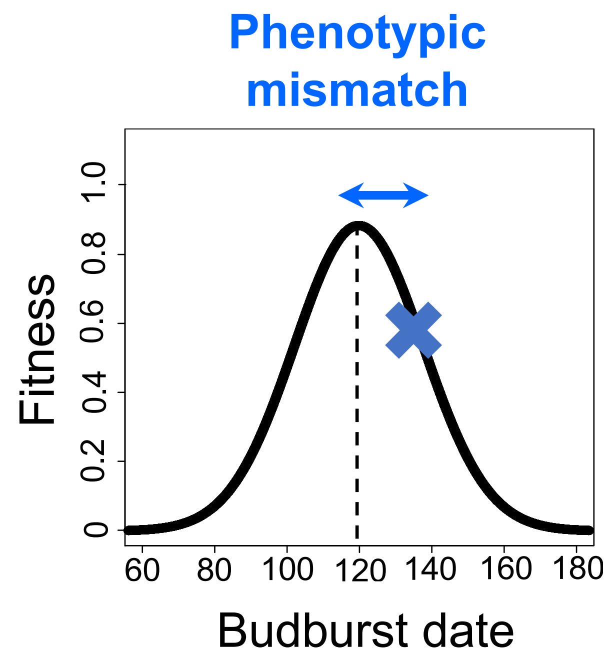




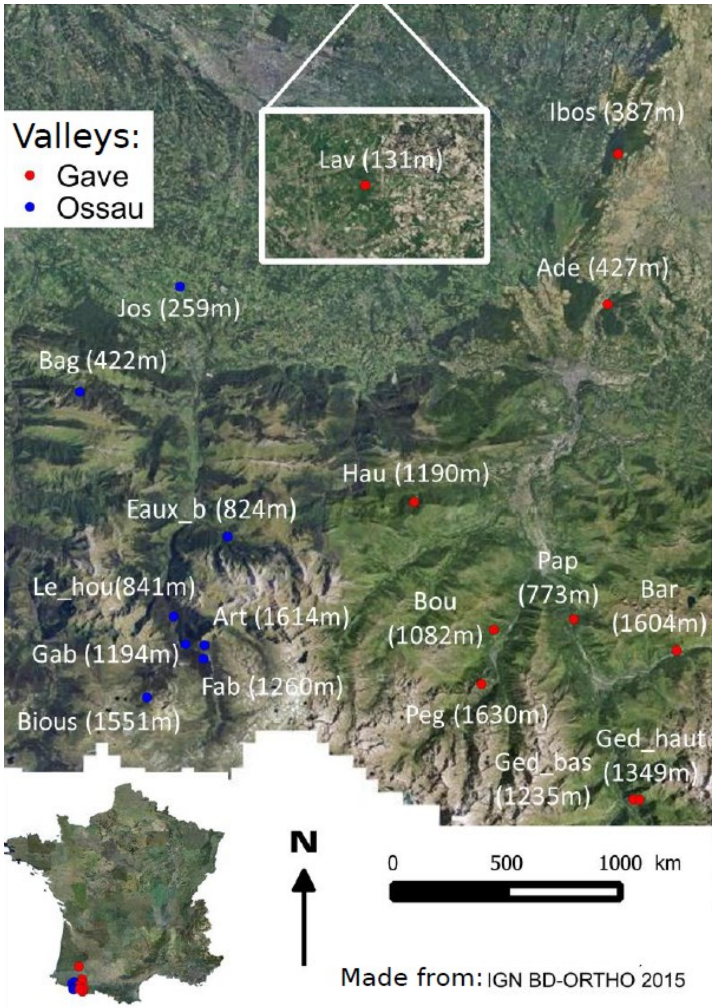
A mechanistic modelling approach

!!! Model does not include evolutionary processes





Study sites and species



<u>Climate</u>: 2 valleys in the Pyrenees
Populations ranging from 100 to 1700 m

<u>Simulation period</u>:
Historical climate 1960-2012
Future climate 2013-2099 (RCP4.5, 8.5)

<u>Species</u>:

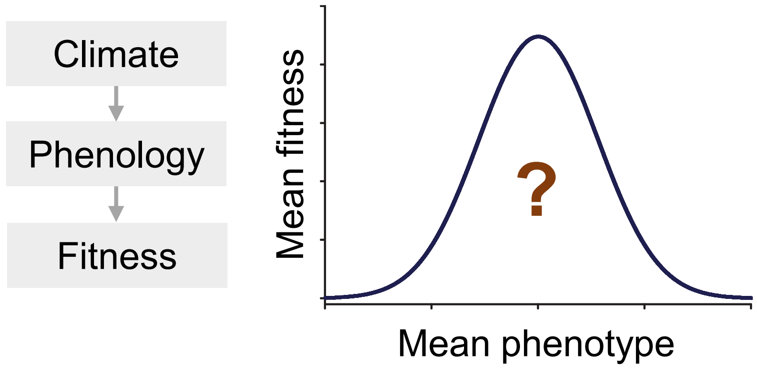
Fagus sylvatica

Quercus petraea

Abies alba

Aims and questions

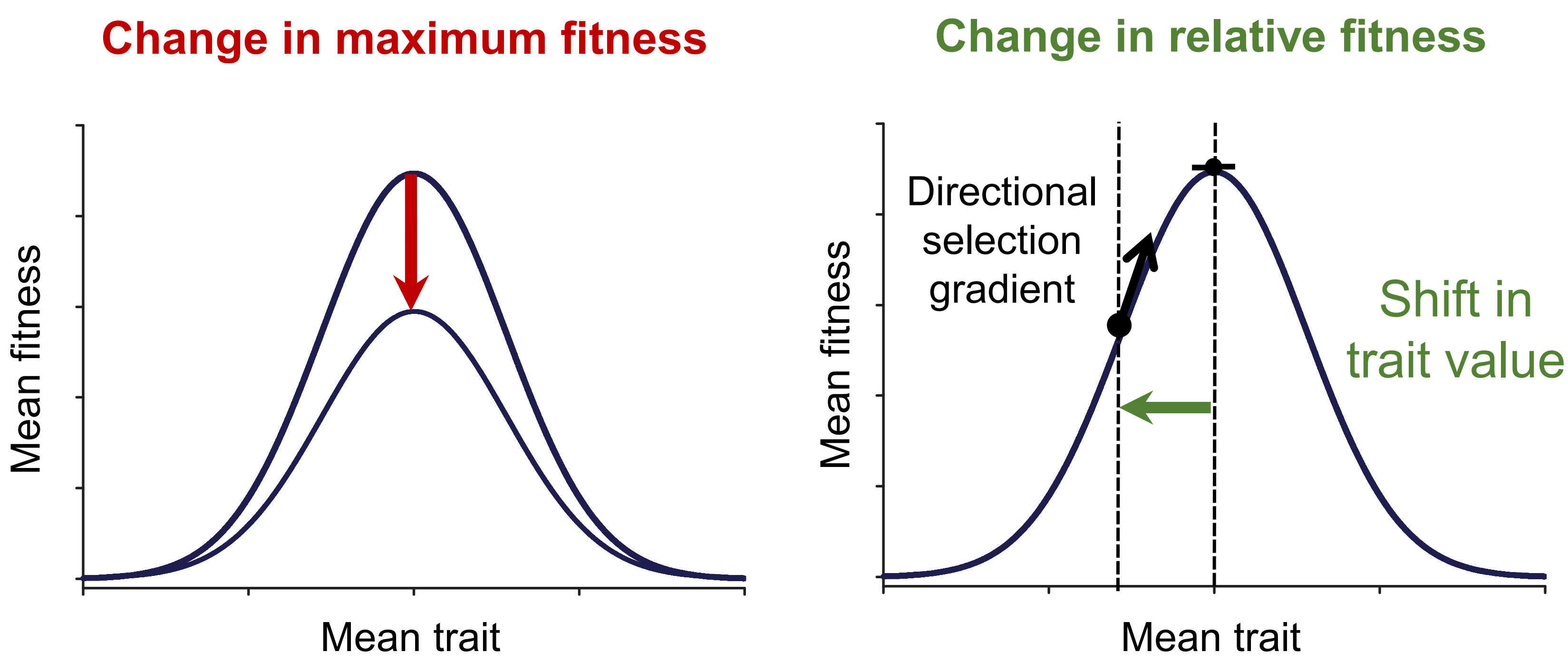
Derive fitness landscapes in tree species from a mechanistic model



How do the optimum and shape of fitness landscapes change with environmental variation ?

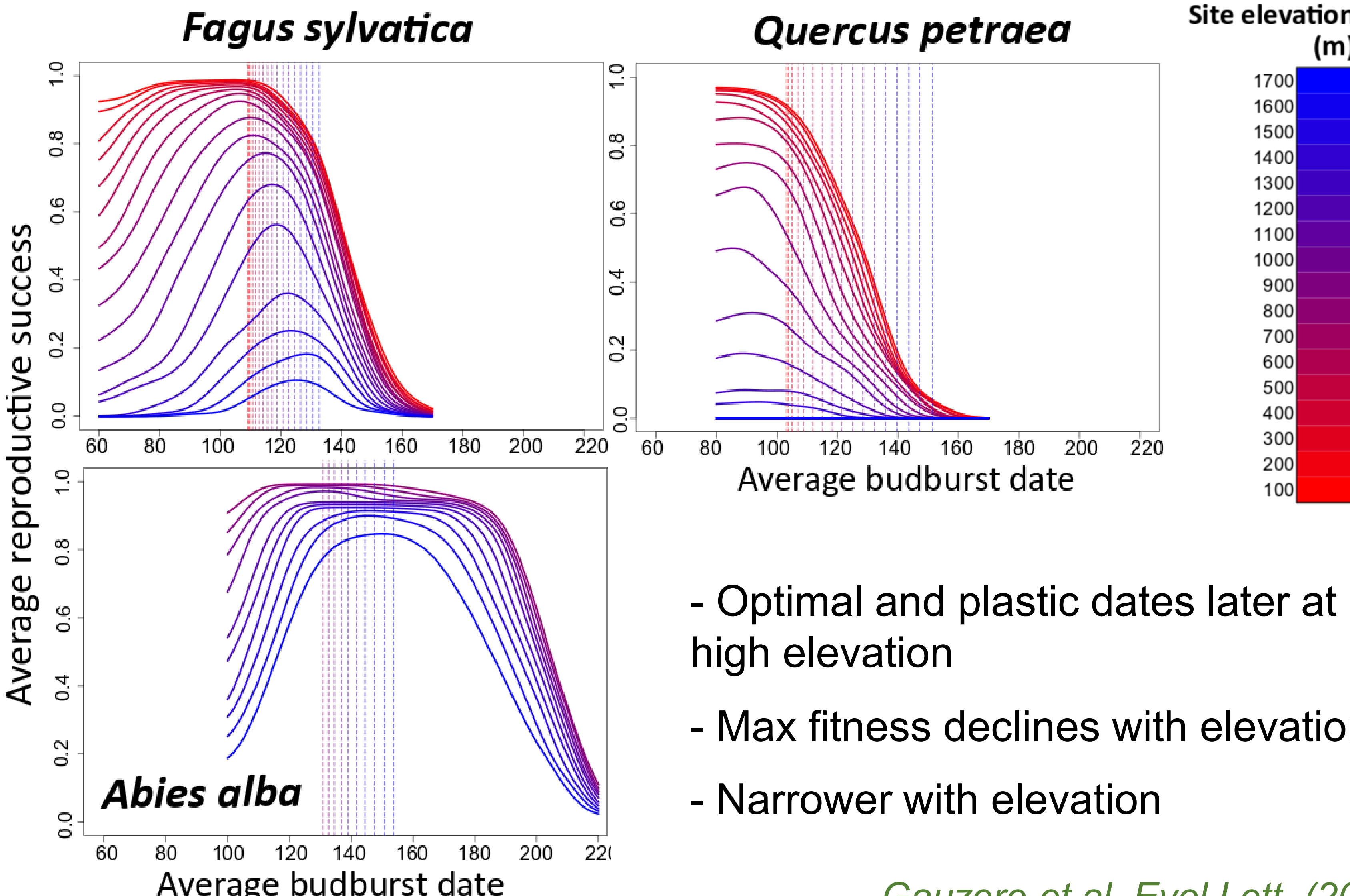
Does phenotypic mismatch lead to maladaptation in future climate ?

Measures of maladaptation



Ecological vs evolutionary perspectives of maladaptation

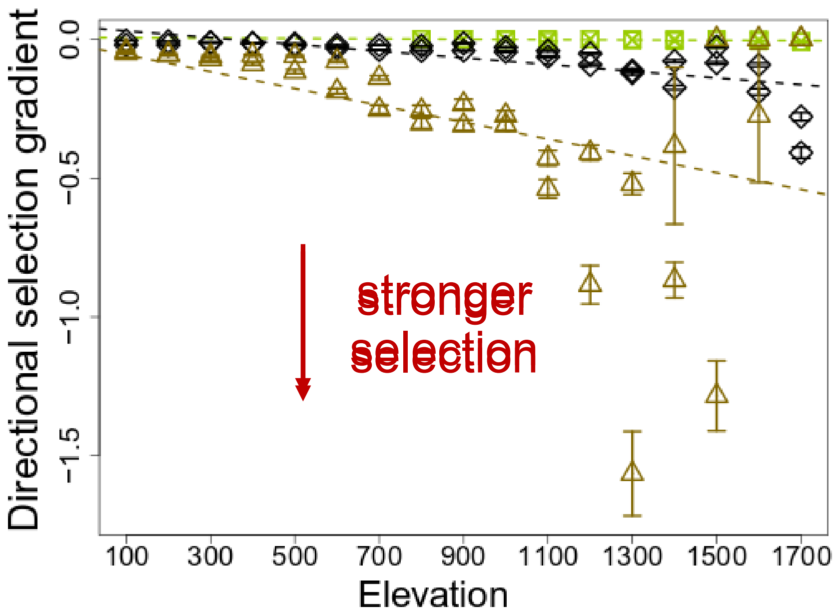
Simulated fitness landscapes - historical

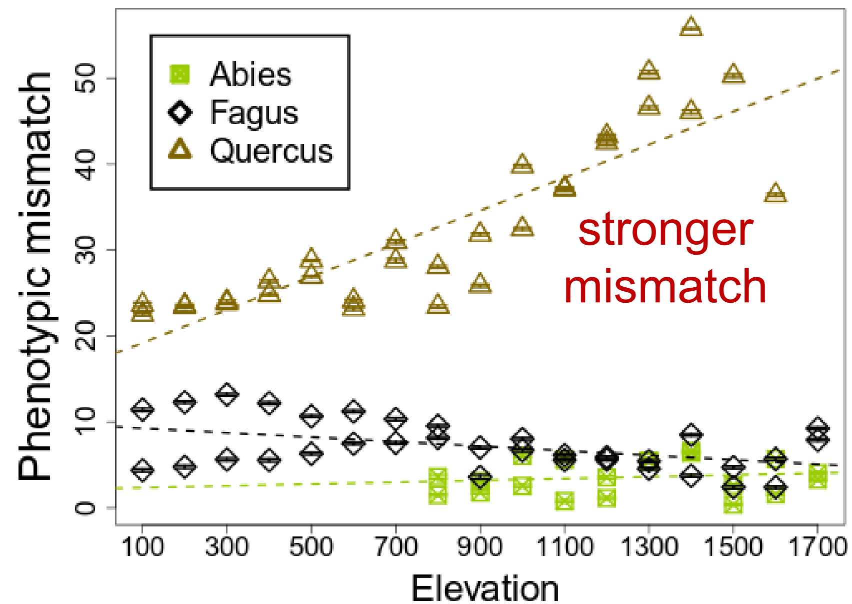


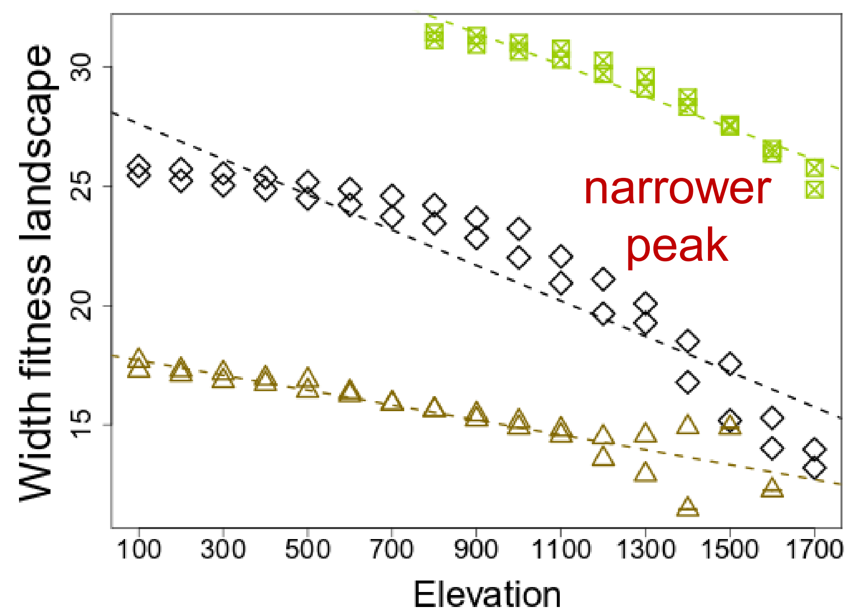
- Optimal and plastic dates later at high elevation
- Max fitness declines with elevation
- Narrower with elevation

Gauzere et al. Evol Lett. (2020)

Selective pressures - historical



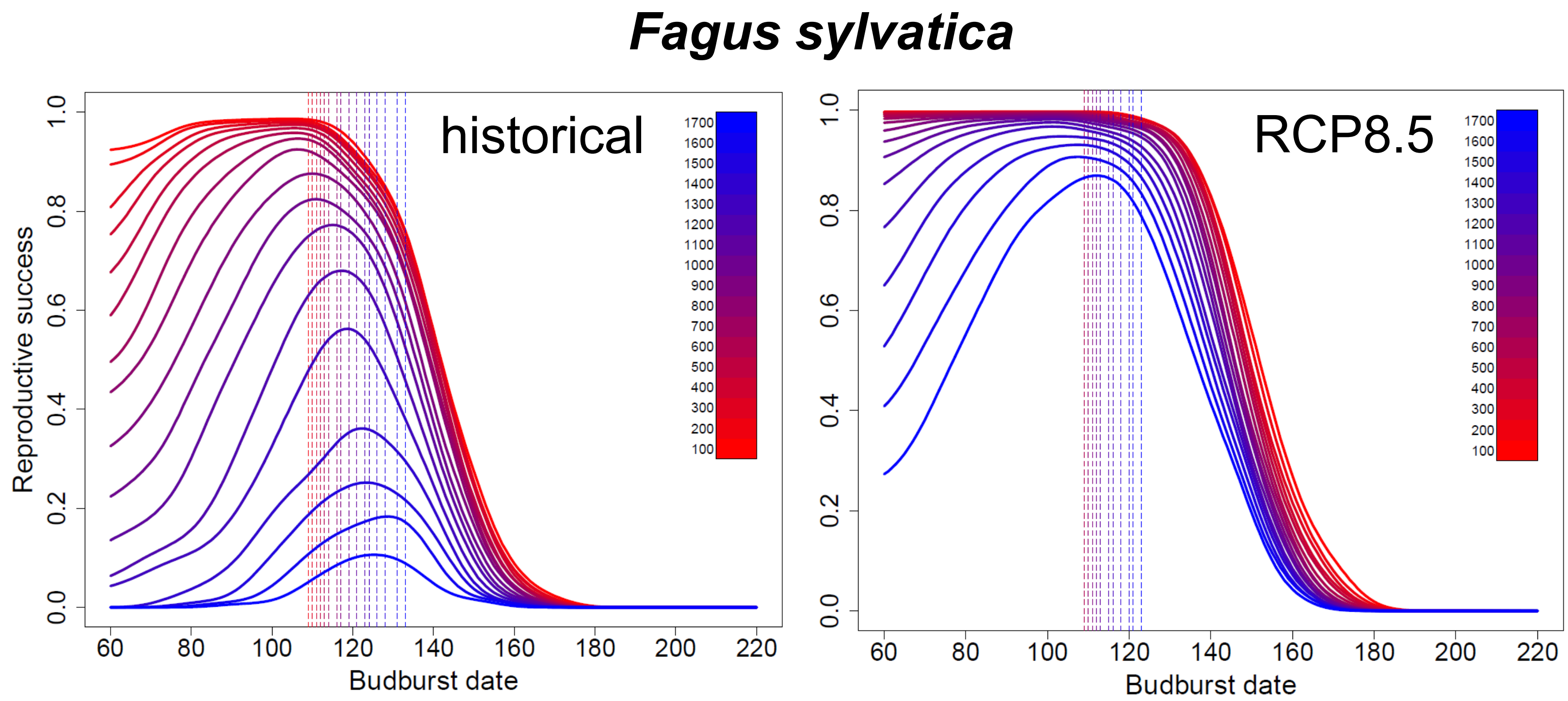




Phenotypic mismatch +
width of the fitness peak =
stronger selection

Gauzere et al. Evol Lett. (2020)

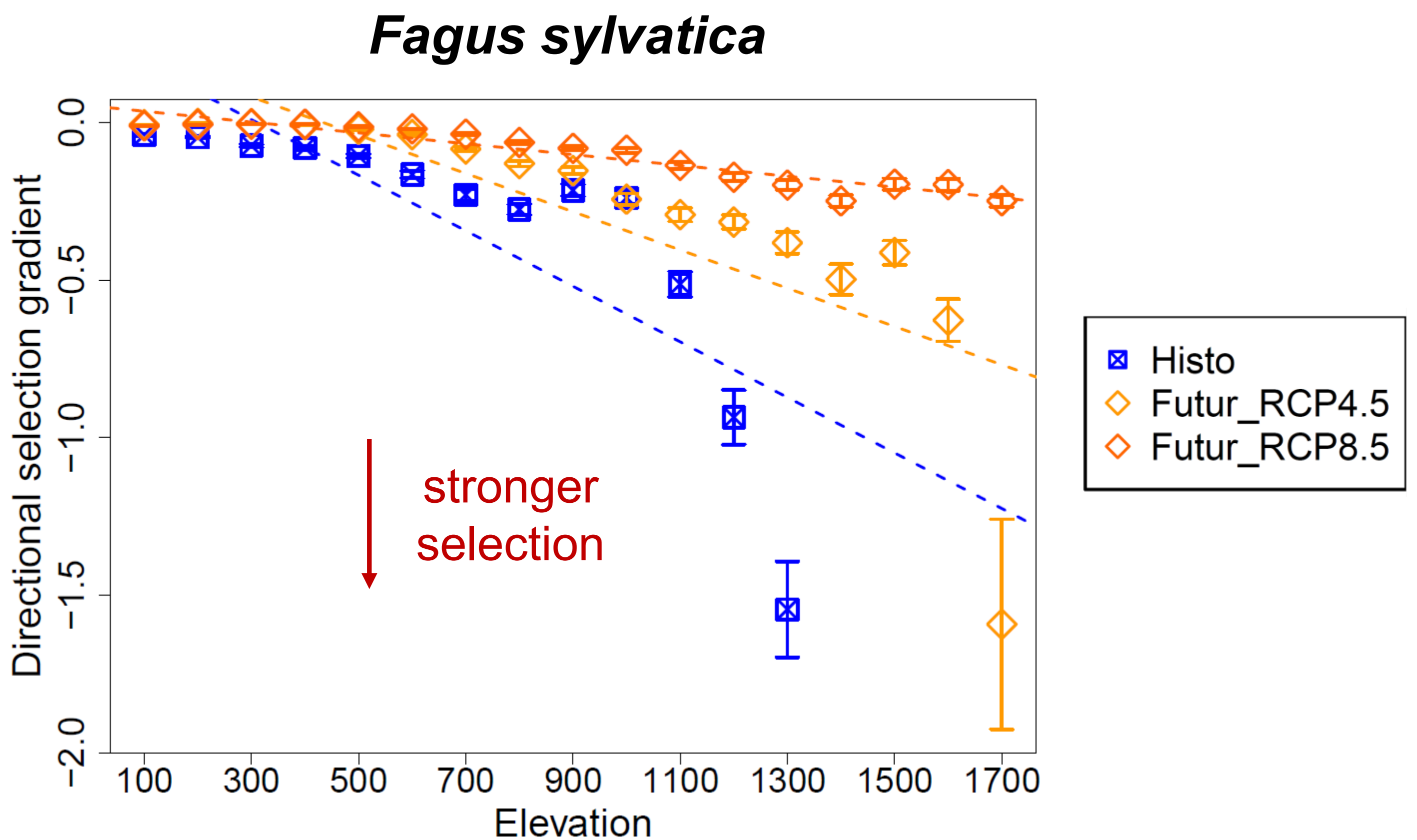
Simulated fitness landscapes - <u>future</u>



- Earlier spring phenology with climate warming, more uniform across elevations

- Larger width of the fitness landscape and increase in max fitness → less constraints on bud development

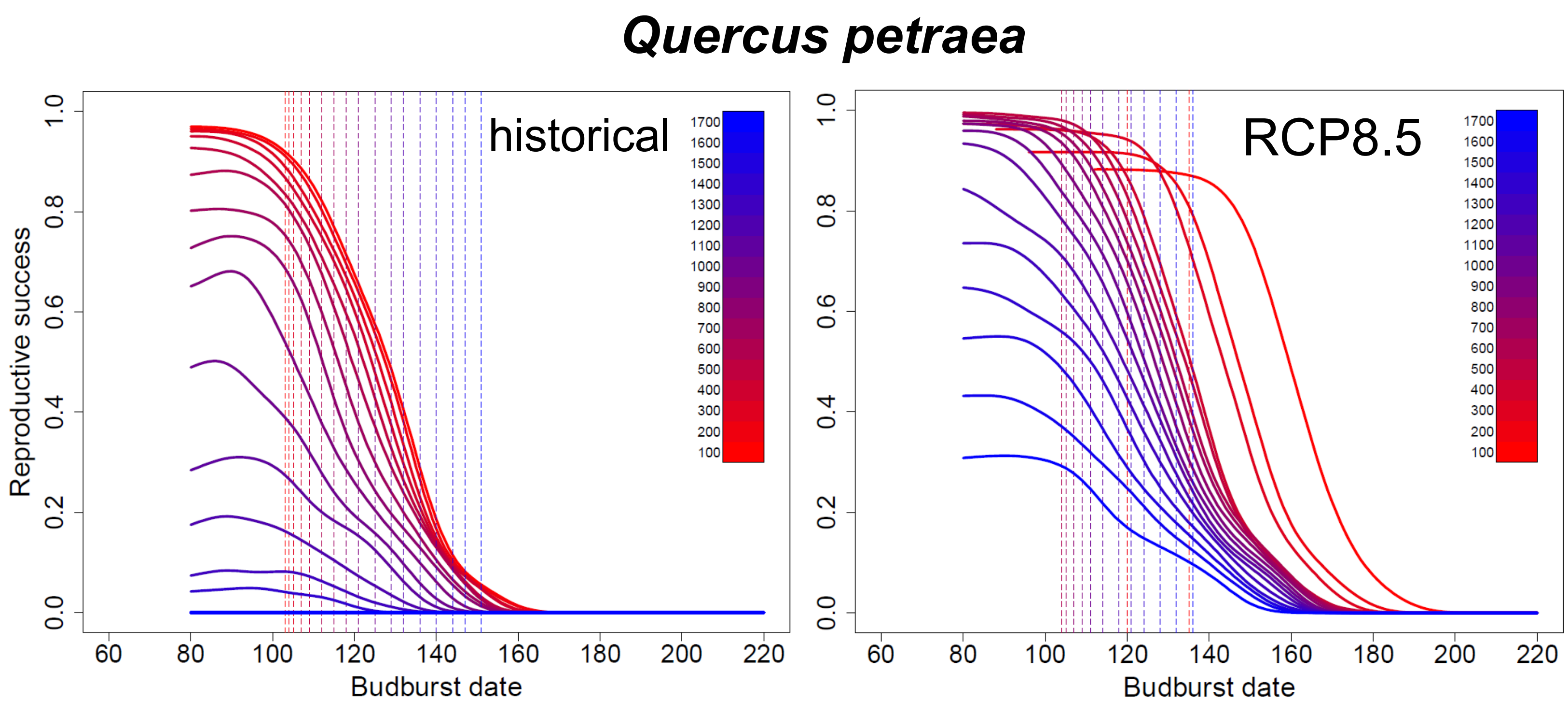
Selective pressures - future



Selection relaxes as climate warms

→ reduction of maladaptation

Simulated fitness landscapes - future



- Max fitness increases at high elevation and decreases at low elevation

- Maladaptation caused by a change in max fitness (also for fir)

Main results and concluding remarks

- Strong change in the shape of fitness landscape, not only the optimum

  → focusing on other parameters of fitness functions than optimum may be critical to accurately predict the rate of environmental change populations can cope with

- Maladaptation would occur because of a change in maximum fitness rather than increased phenotypic mismatch

  → relaxed selective pressures for earlier spring phenology with climate warming

⚠ Results are highly dependent on the assumption of the PHENOFIT model (e.g., hydraulic failure not modelled)

Acknowledgments

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