



Modélisation de la niche écologique : dimensions fonctionnelle et évolutive

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Plan

Chapitre 1 - Contexte et concepts

Chapitre 2 - Les modèles de niche fondamentale basés sur les processus

Chapitre 3 - De la niche potentielle à la niche réalisée

Rappels sur la niche réalisée

Modélisation de la migration

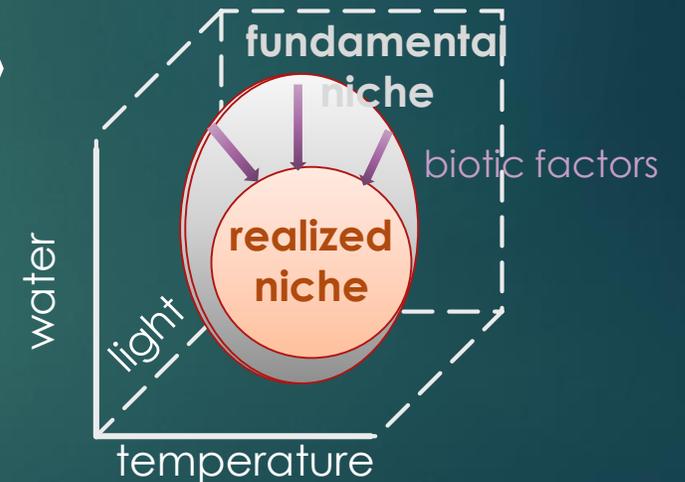
Modélisation de l'évolution génétique de la niche

Rappels

Niche fondamentale :

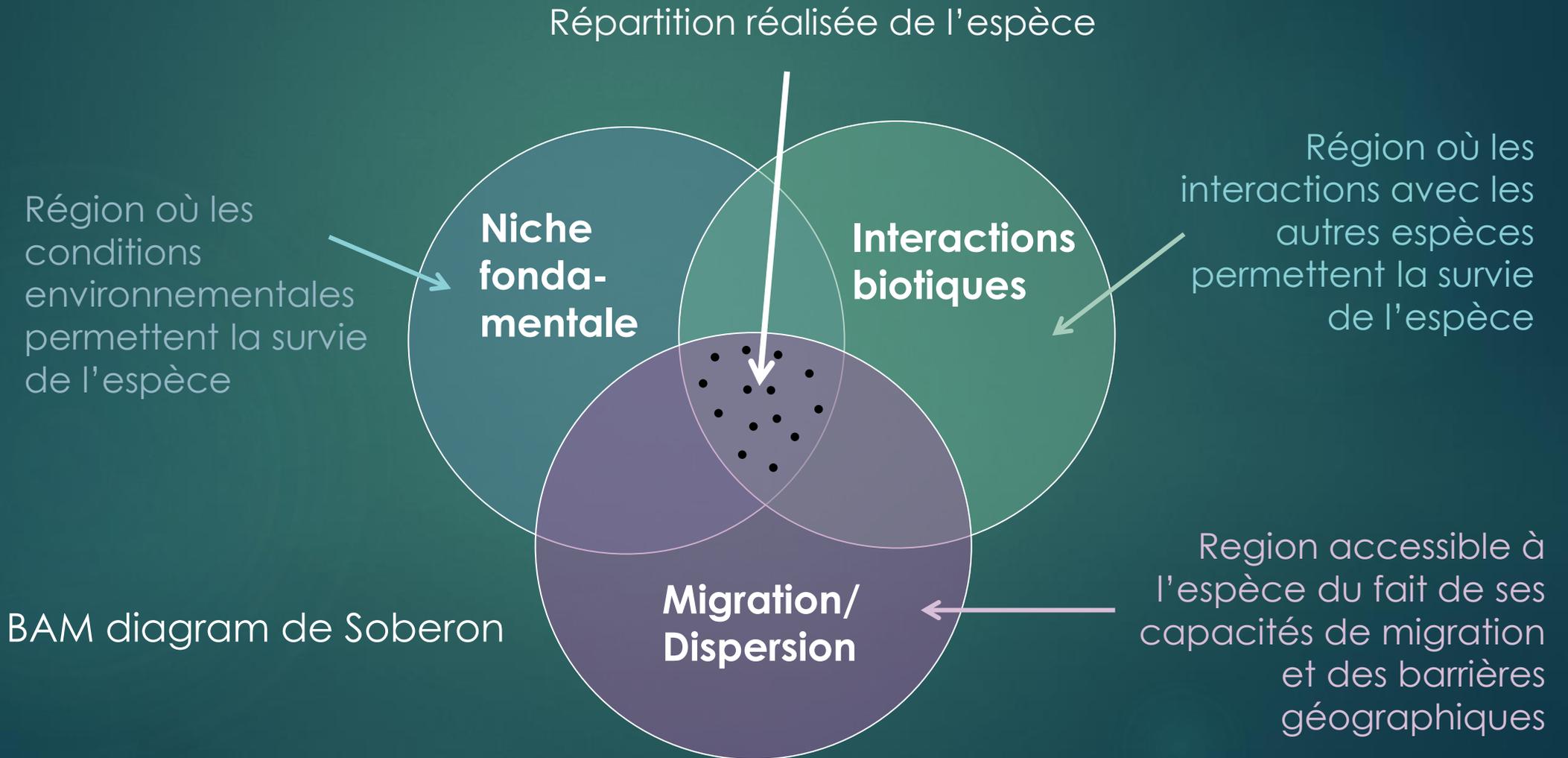
« Ensemble des conditions abiotiques (environnementales) dans lesquelles une population peut se développer indéfiniment »

Niche réalisée : Part de la niche fondamentale dans laquelle l'espèce est restreinte à cause des interactions avec d'autres espèces.



Hutchinson 1957 - Cold Spring Harbor Symposium on Quantitative Ecology

Rappels



Comment passer de l'aire de répartition potentielle à l'aire réalisée ?

Modèle de niche réalisée =

Modèle de niche fondamentale +

- Modèle de migration
- Modèle de compétition interspécifique
- Modèle de perturbation
- Modèle démographique
- Modèle d'évolution de la niche...

Comment passer de l'aire de répartition potentielle à l'aire réalisée ?

Modèle de niche réalisée =

Modèle de niche fondamentale +

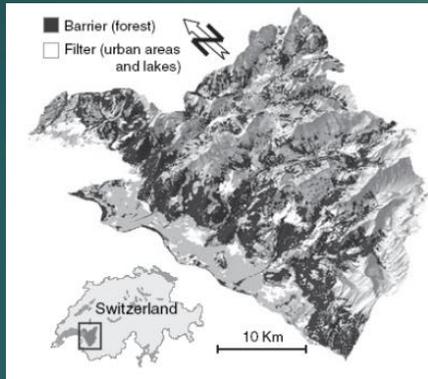
- *Modèle de migration*
- Modèle de compétition interspécifique
- Modèle de perturbation
- Modèle démographique
- *Modèle d'évolution de la niche...*



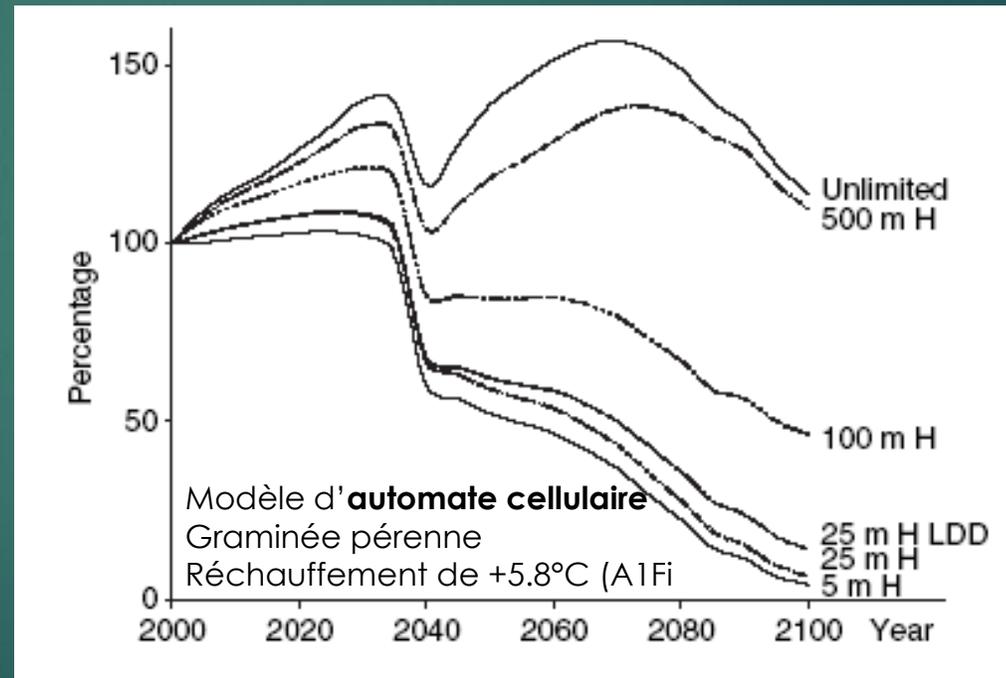
2. Modélisation de la migration des espèces

Importance de la migration

Evolution du pourcentage de surface occupée selon le potentiel de migration de l'espèce



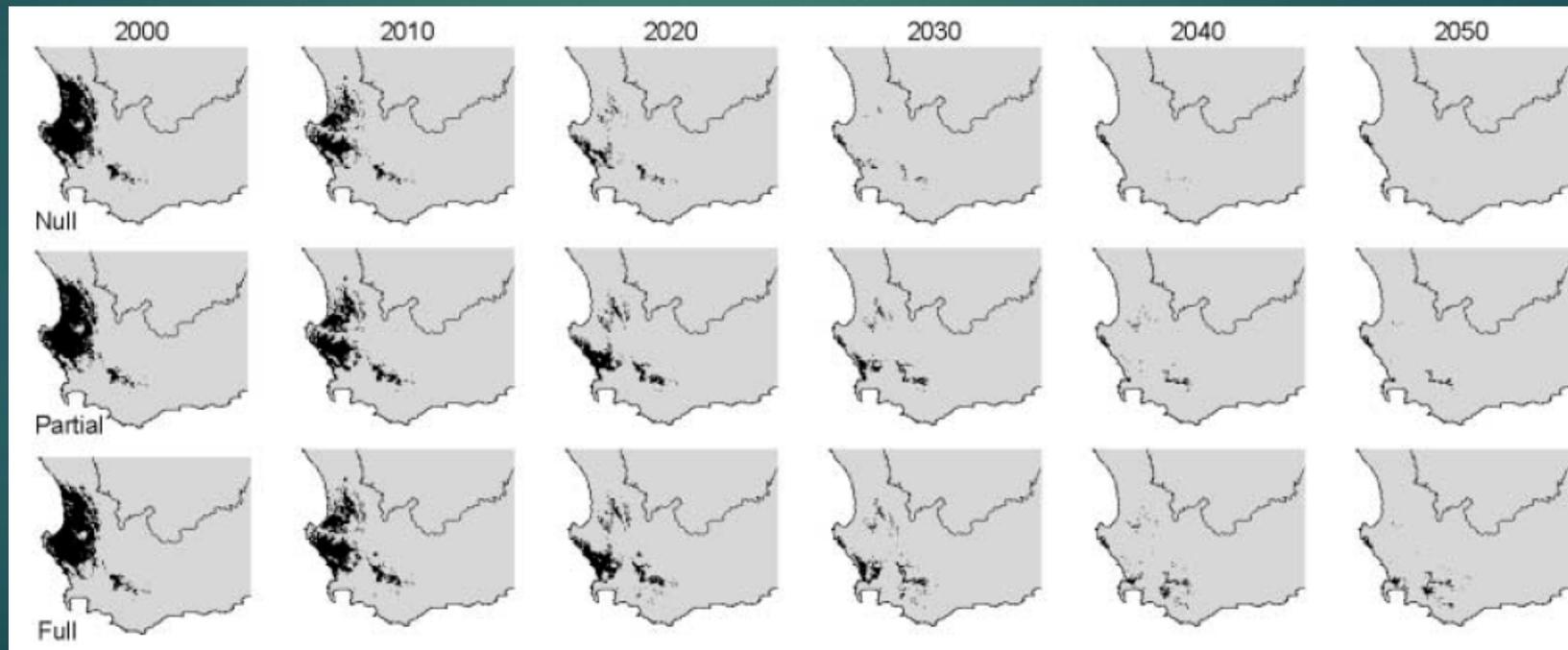
Engler et Guisan 2009



- Les incertitudes sur le potentiel de migration des espèces sont aussi importantes que celles sur les scénarios climatiques

Comment simuler la migration ?

Prédiction de la répartition de *Leucospermum rodolentum* dans la région du Cap – **Modèle d'automate cellulaire**



No
dispersion

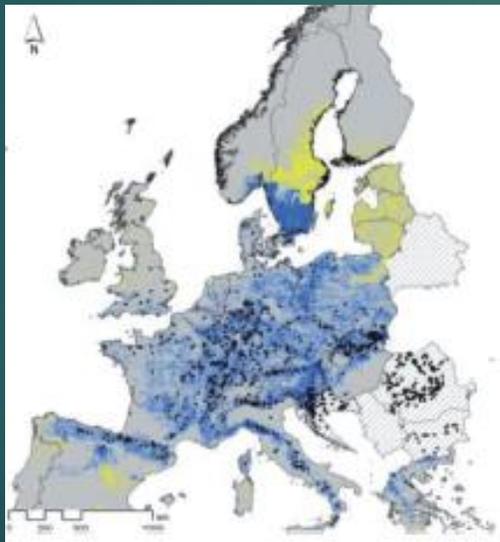
Limited dispersion:
cellular automata
with constant migration
rate of 2 pixels per decade

limited
dispersion

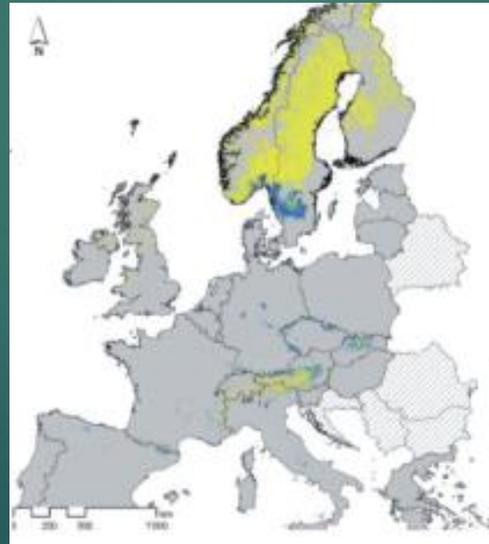
Comment simuler la migration ?

Répartition du hêtre simulée à l'aide d'un SDM corrélatif +
automate cellulaire + modèle TreeMig

2000

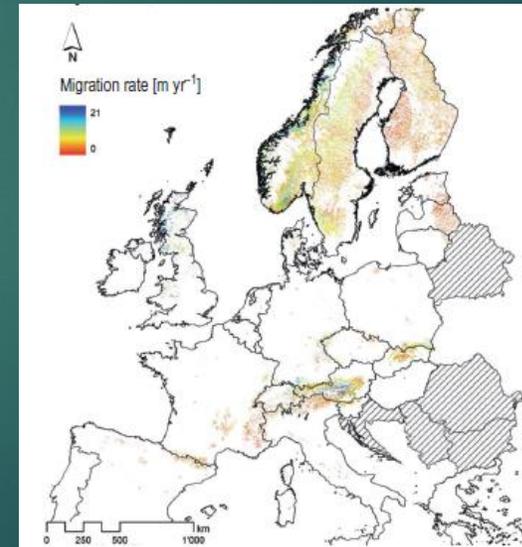


2100 (A1fi/GRAS)



mean migration rate

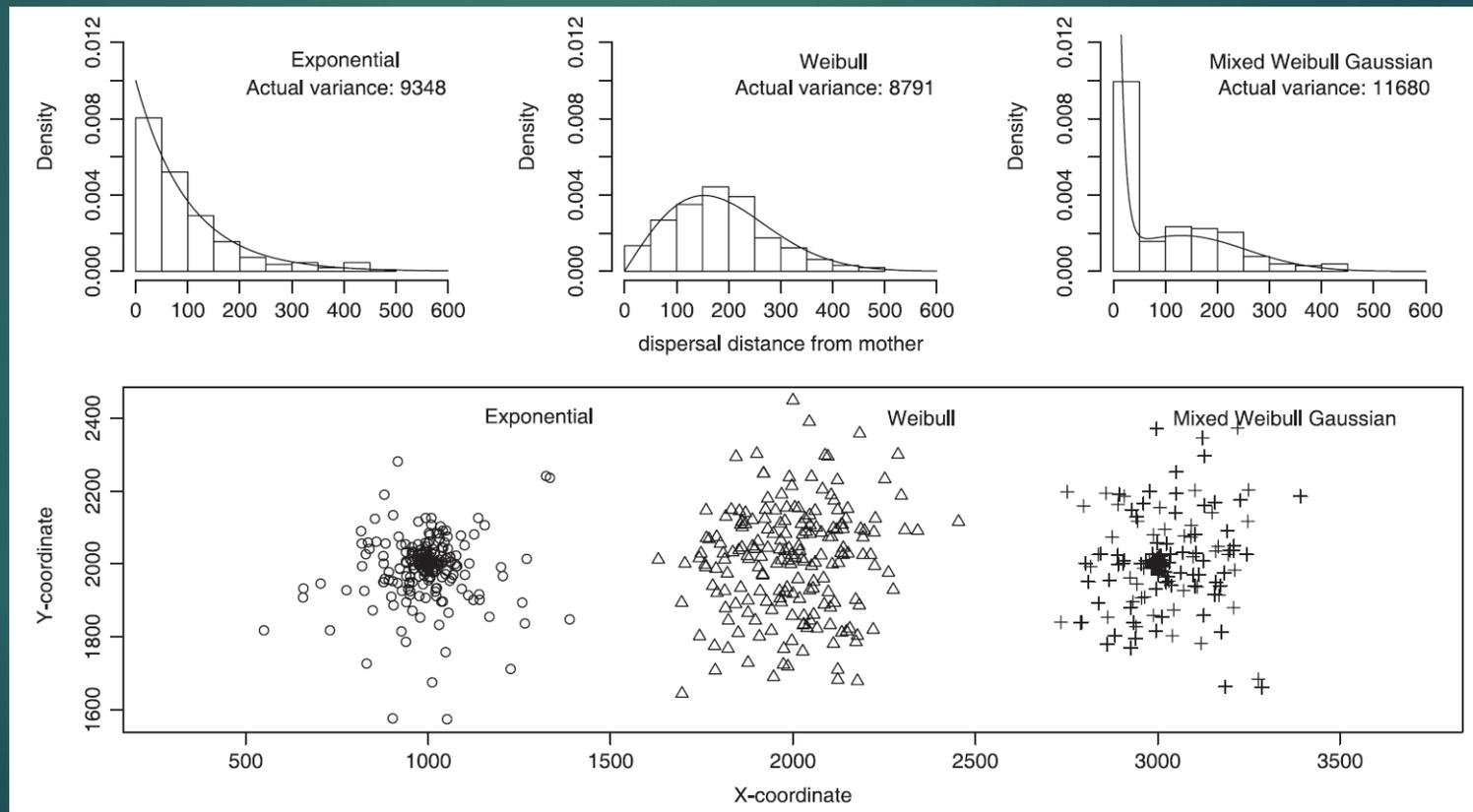
Mean = 1.1 m.yr⁻¹(±1.7m.yr⁻¹)



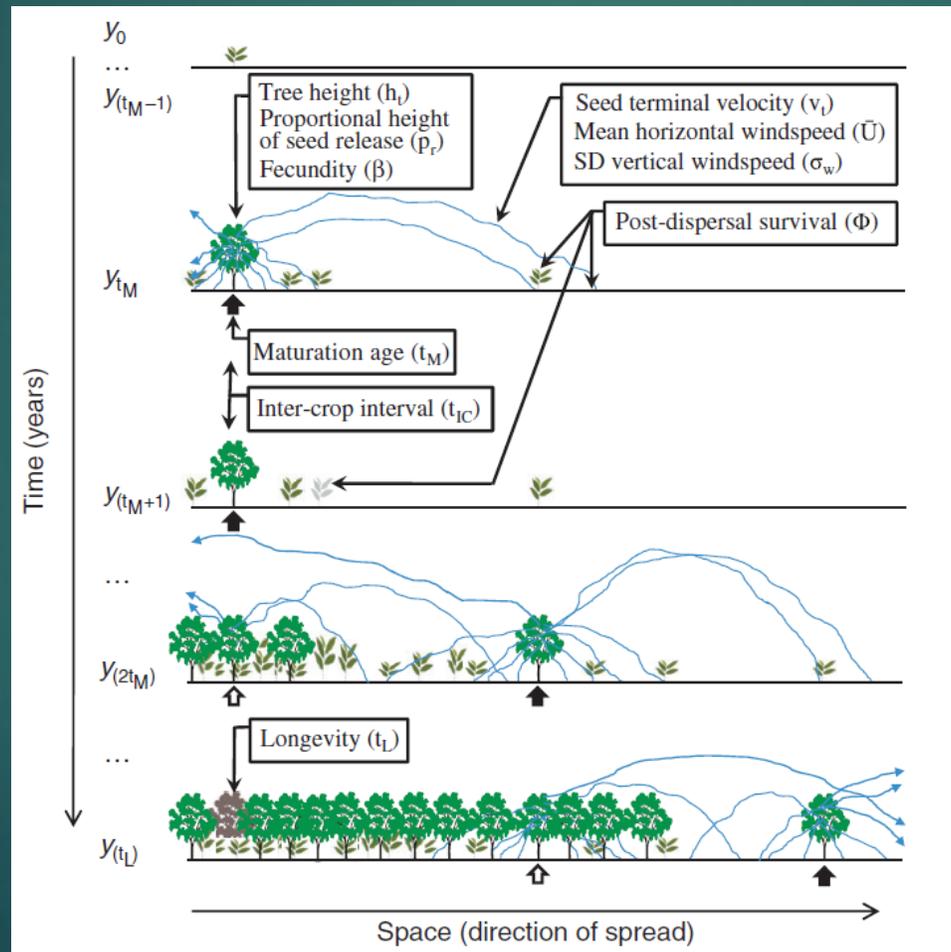
- No migration scenario
- Realistic migration scenario
- Unlimited migration scenario
- *F. sylvatica* in ICP Forest Level 1
- Areas of model predictions
- Additional areas for model calibration

Comment simuler la migration ?

Modélisation des pluies de graines à l'aide de kernels de dispersion



Comment simuler la migration ?



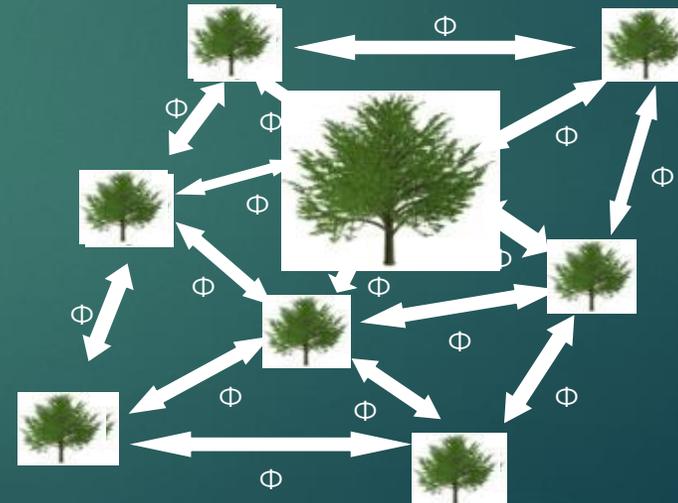
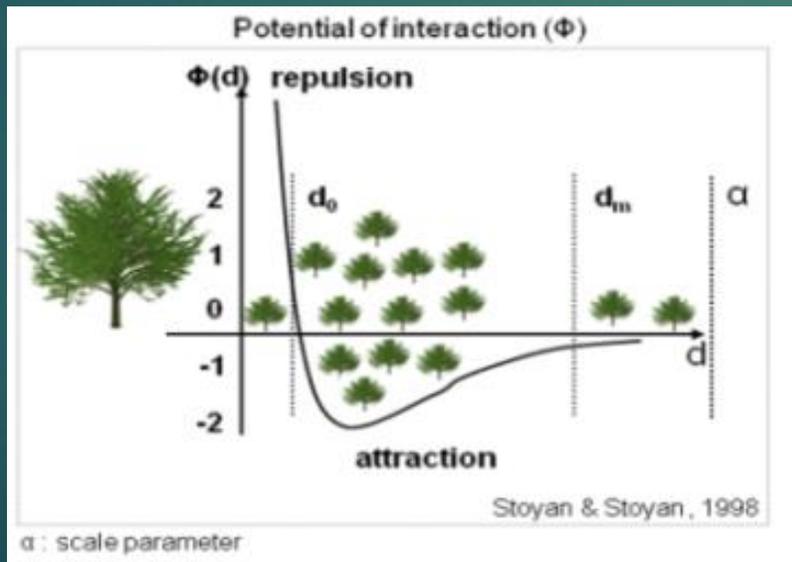
Modélisation de la dispersion des graines par le vent d'une espèce d'arbre anémochore - **Modèle mécaniste**

Simuler une migration réaliste

Utilisation d'un processus ponctuel de Gibbs inhomogène (Stoyan & Stoyan 1998) pour simuler la dispersion

Principe :

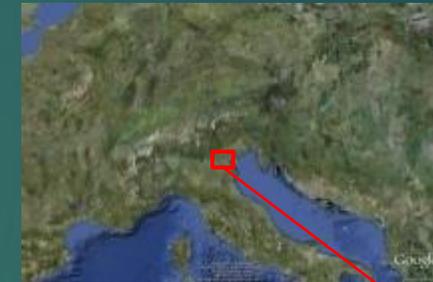
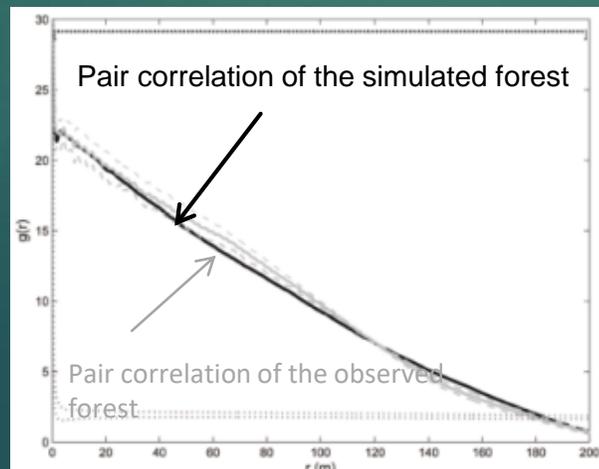
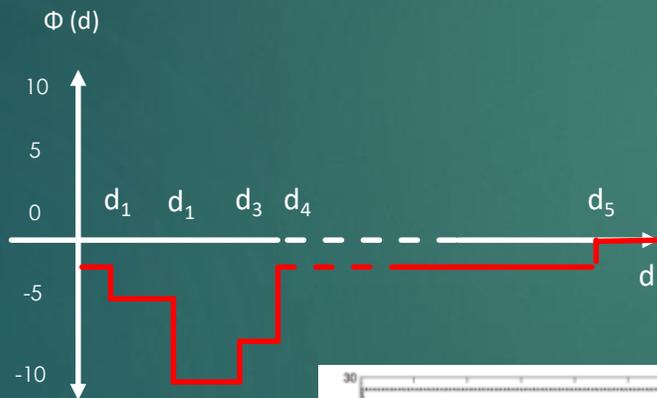
Le potentiel d'interaction du processus ponctuel résume à lui seul tous les processus de dispersion et de post-dispersion responsables de la structure spatiale du peuplement



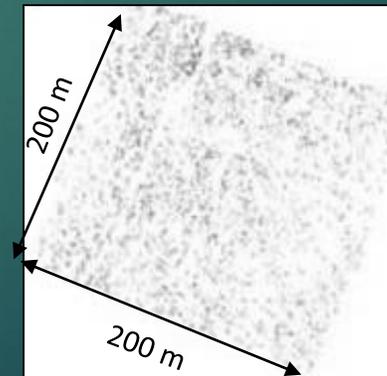
Simuler une migration réaliste

Utilisation d'un processus ponctuel de Gibbs pour simuler la dispersion

Calibration du potentiel d'interaction



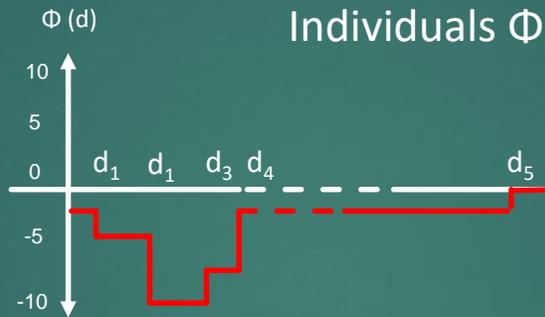
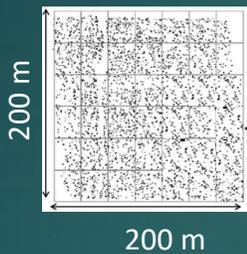
Forêt de hêtres en front de colonisation



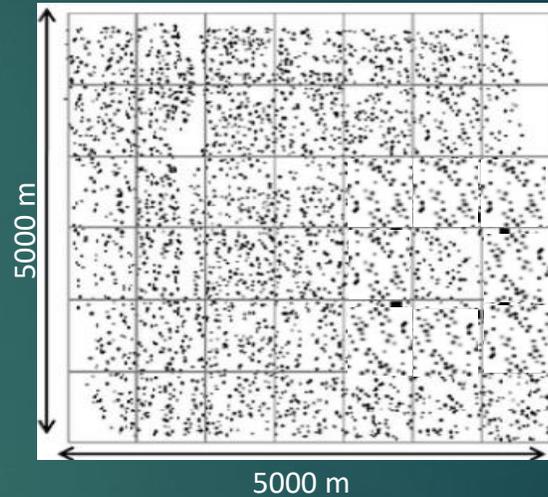
Simuler une migration réaliste

Changement d'échelle

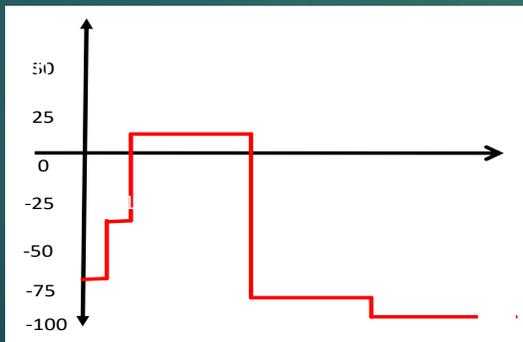
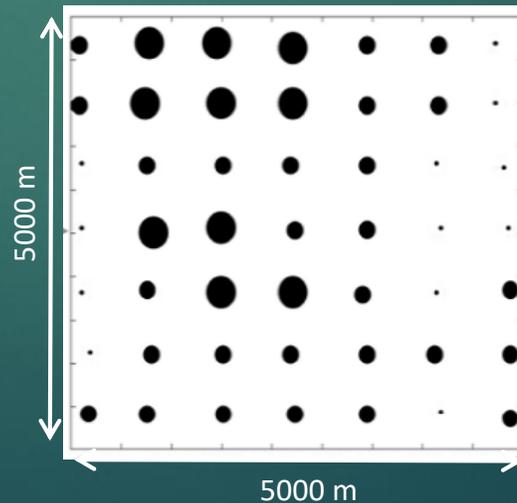
Individuals map
Observed forest



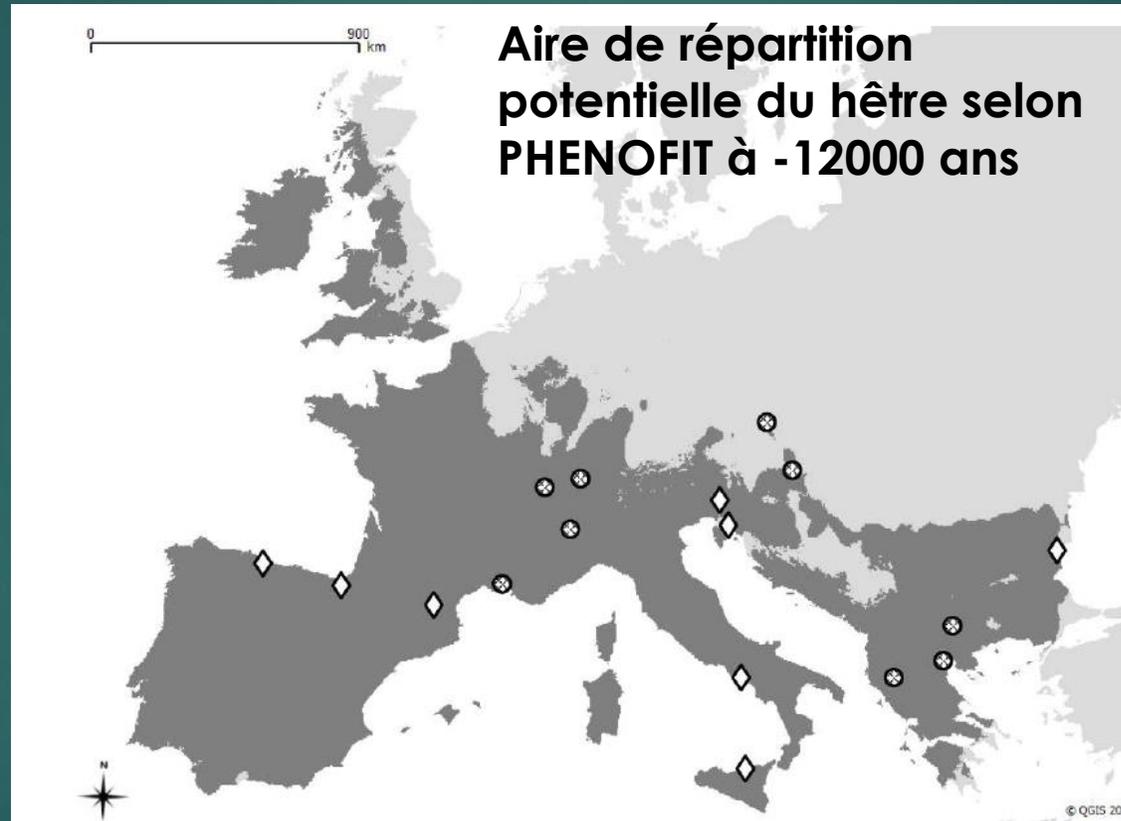
Individuals map
Simulated forest



Cohorts map
Simulated forest

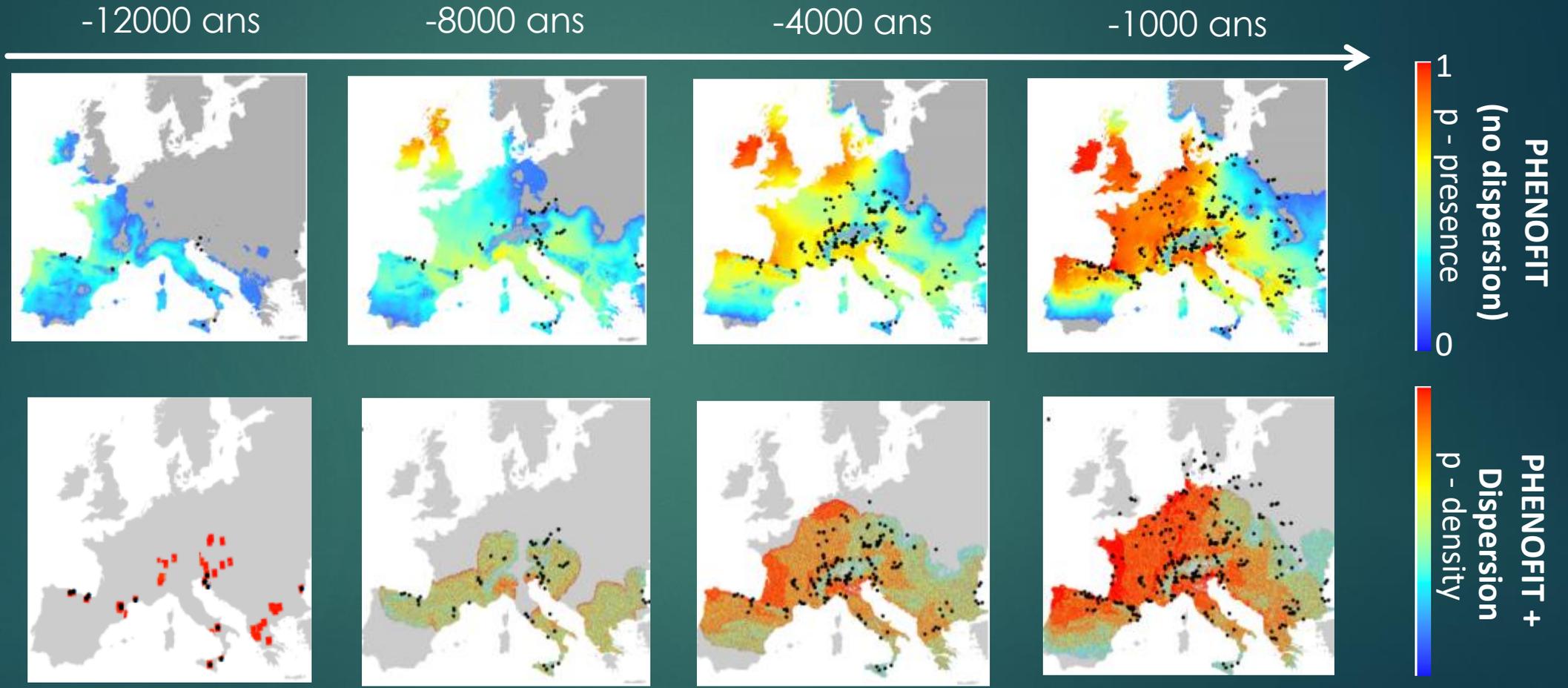


Simuler une migration réaliste



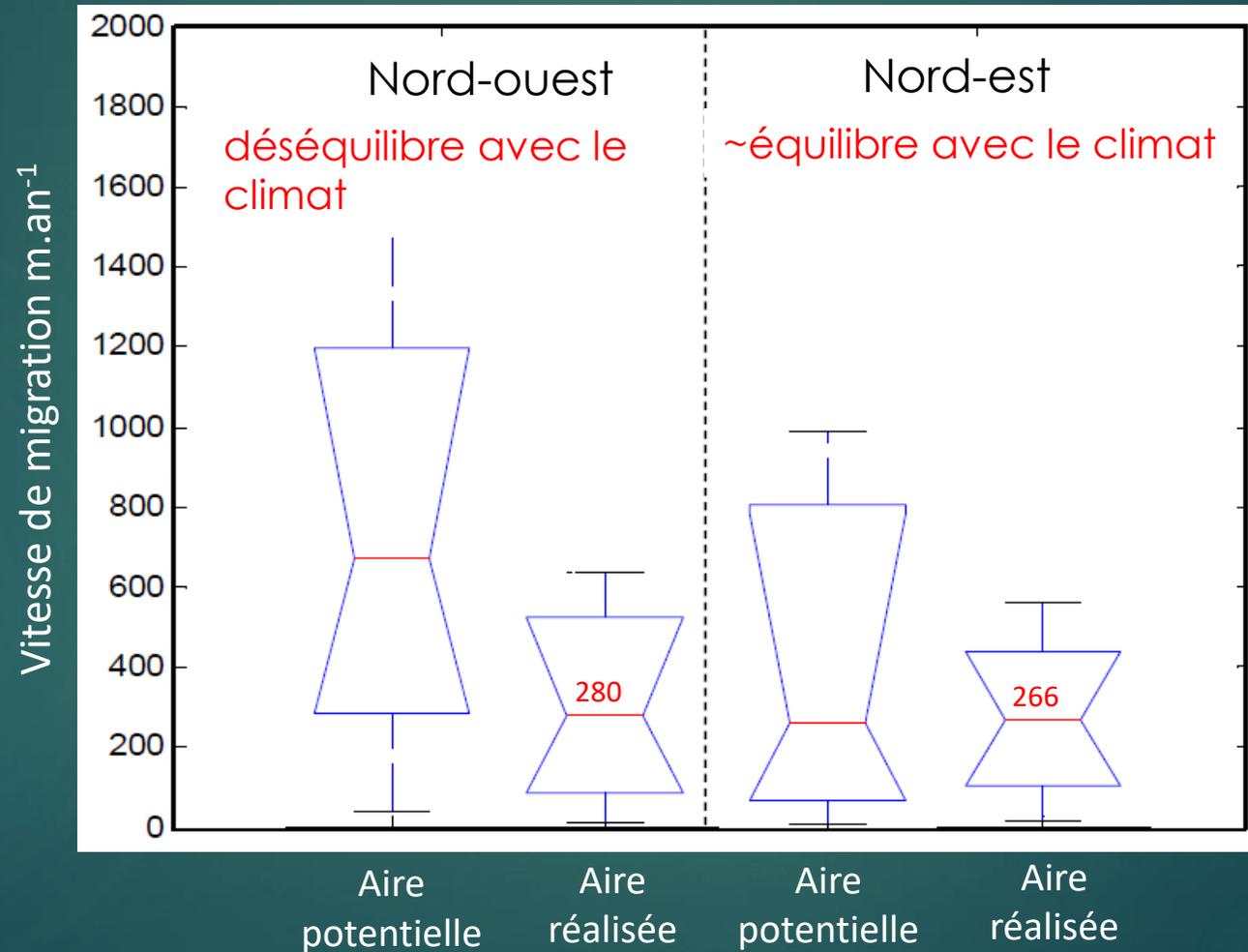
- Suitable habitats at 12kys BP according to PHENOFIT and Davis et al. 2003 climatic data
- ◆ Major refugia (macrorests, pollen >2% , Magri et al. 2006)
- Suspected refugia (phylogeography, Magri et al. 2006)

Simuler une migration réaliste



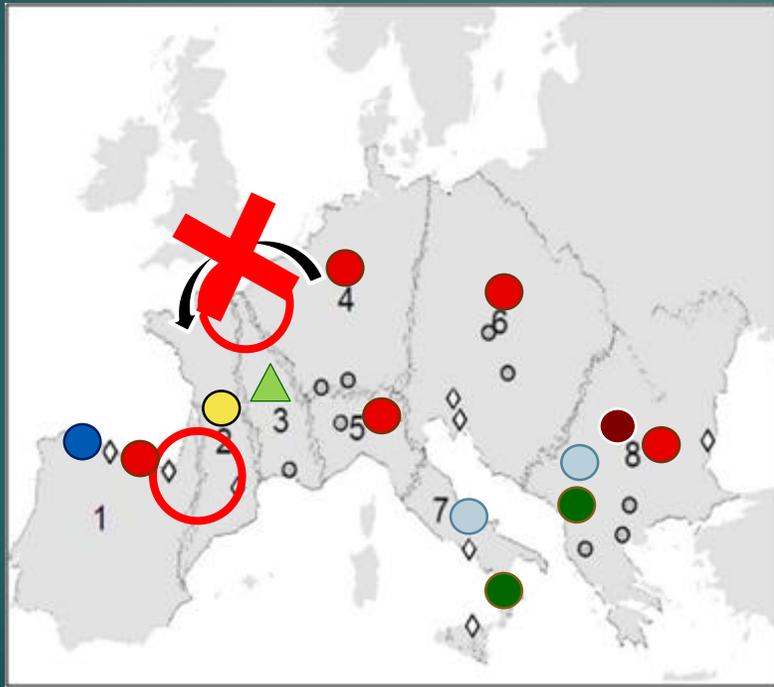
• Pollen >2%

Simuler une migration réaliste

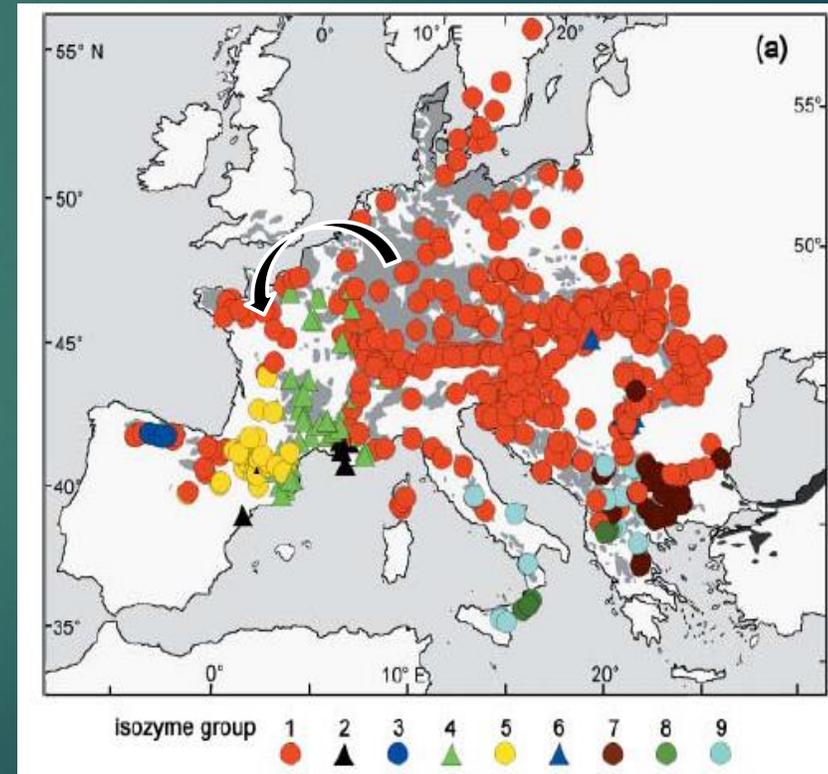


Simuler une migration réaliste

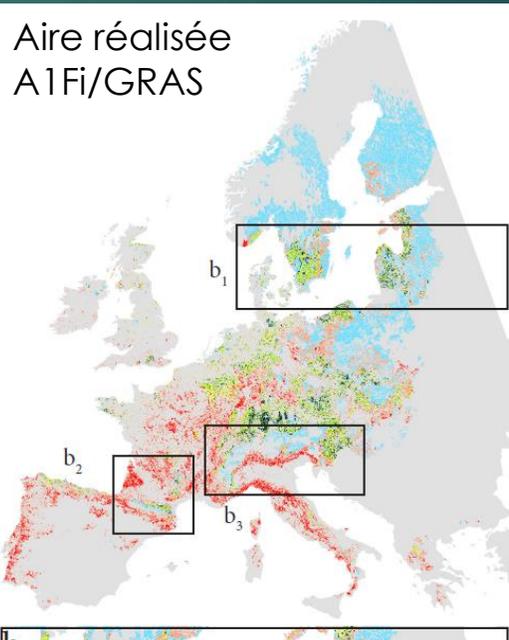
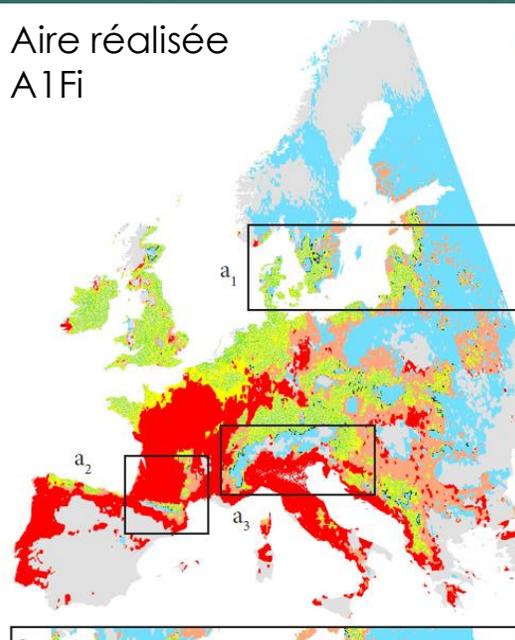
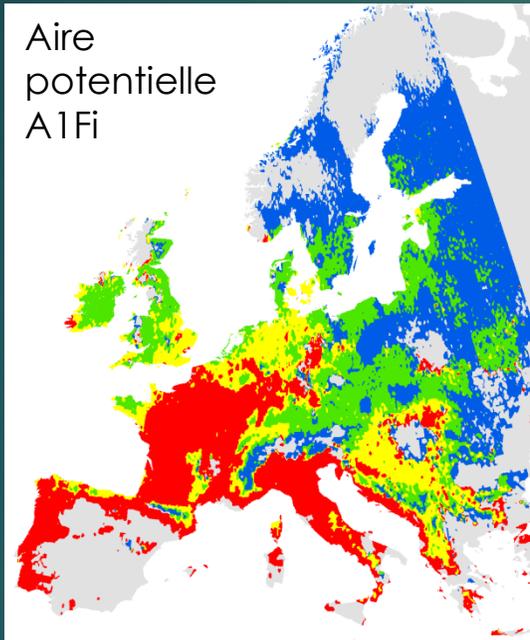
Contribution des différents refuges à la répartition actuelle du hêtre



Distribution des groupes d'isozymes (Magri et al. 2006)



Simuler une migration réaliste

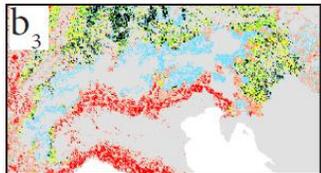
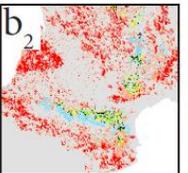
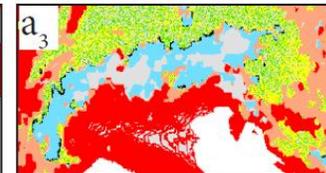
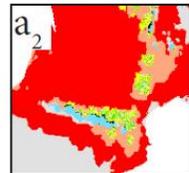
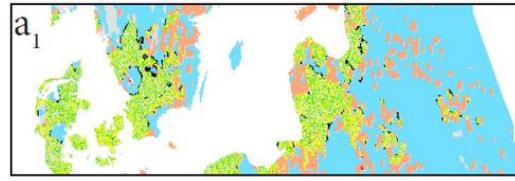


- Extinction
- En sursis
- Baisse de densité de population
- Colonisation
- Aire colonisable
- Hausse de densité de population

Mean expansion rate realized : 22-44 m.yr⁻¹
potential : 152-207 m.yr⁻¹

Mean extinction rate: realized : 154-333 m.yr⁻¹
potential: 109-284 m.yr⁻¹

Répartition du hêtre en 2100





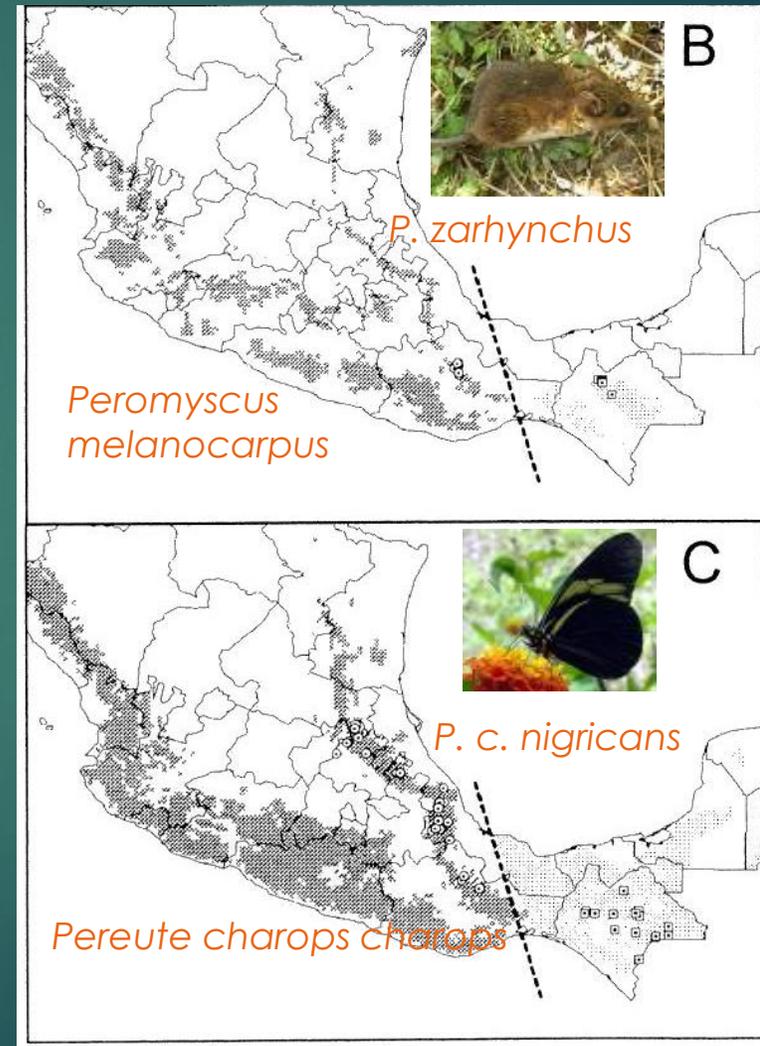
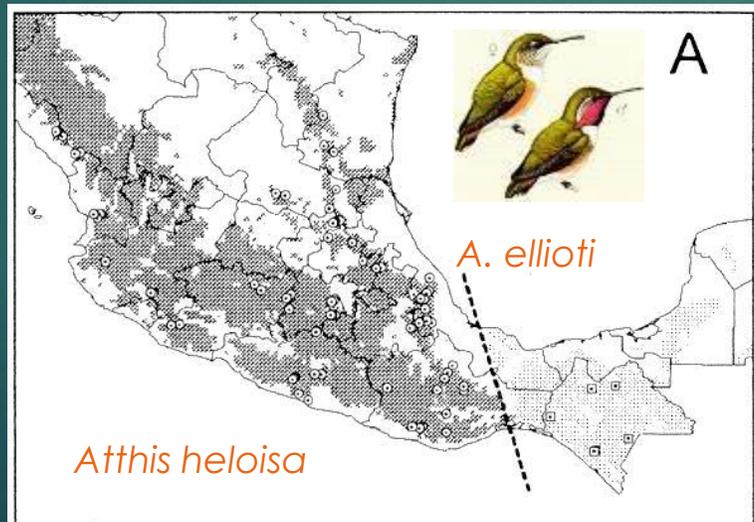
3. Modélisation de l'évolution de la niche

La niche évolue-t-elle ?

Conservatisme de niche ?

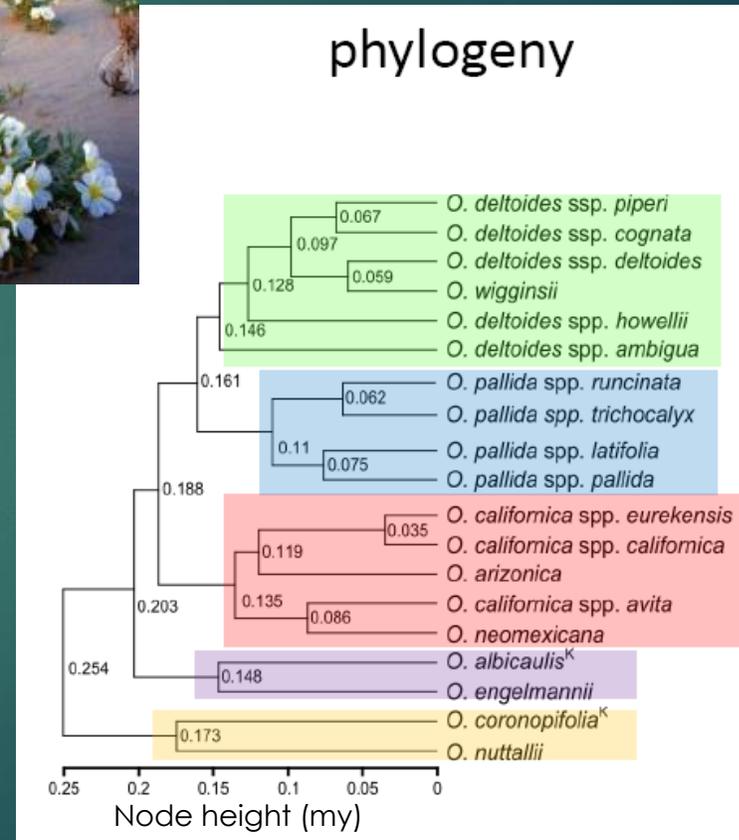
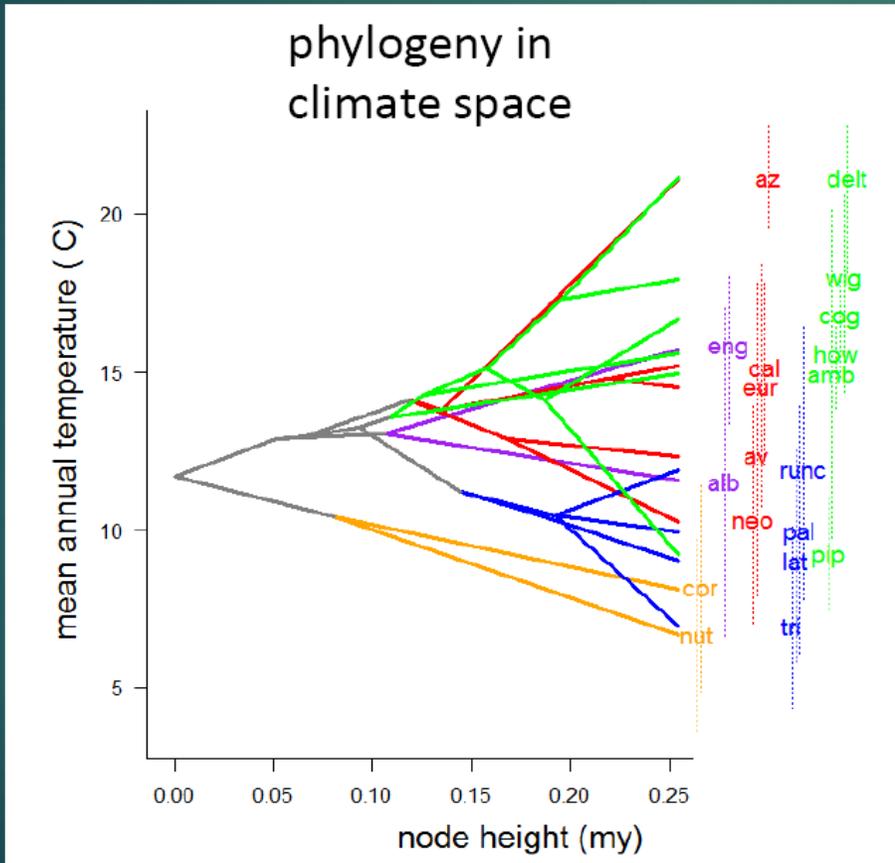
37 pairs of sister-species isolated since
2-10x10⁶ years apart from the
Tehuantepec isthmus, Mexico

Peterson et al. Science 1999



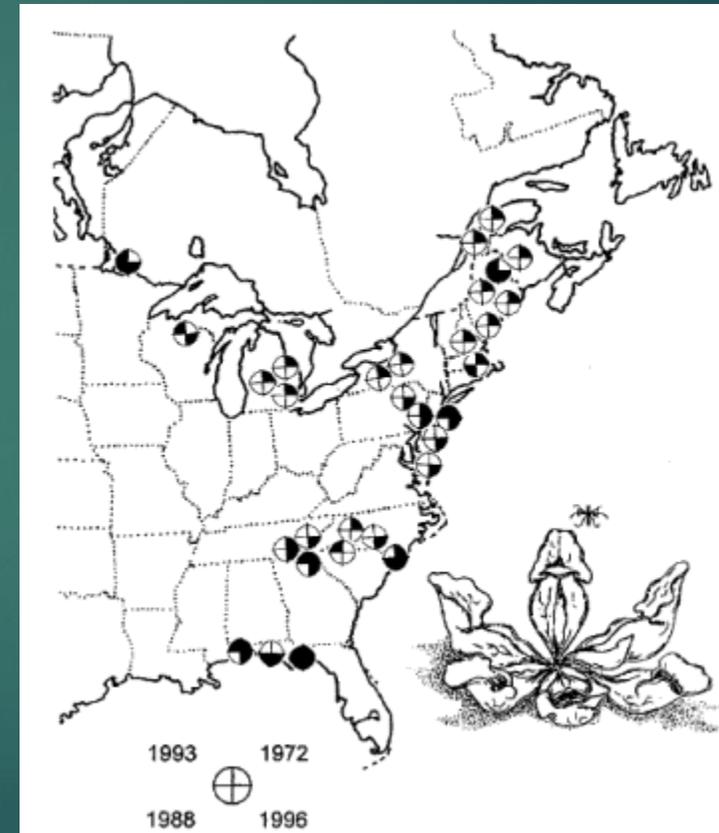
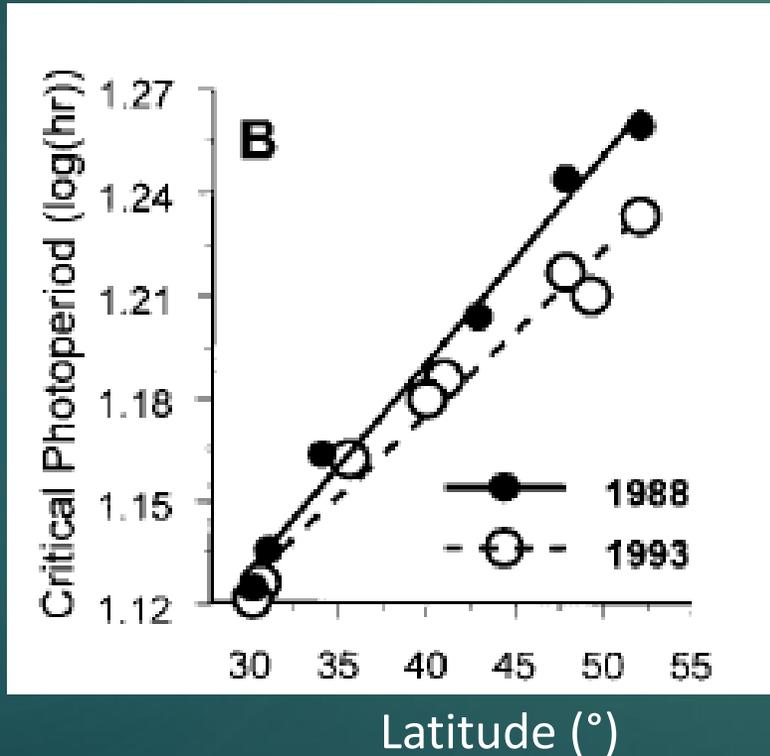
La niche évolue-t-elle ?

Oenothera, 19 taxa, Western USA



La niche évolue-t-elle ?

Mosquito *Wyeomyia smithii* niche evolved in a few years



L'évolution génétique des traits définissant la niche fondamentale

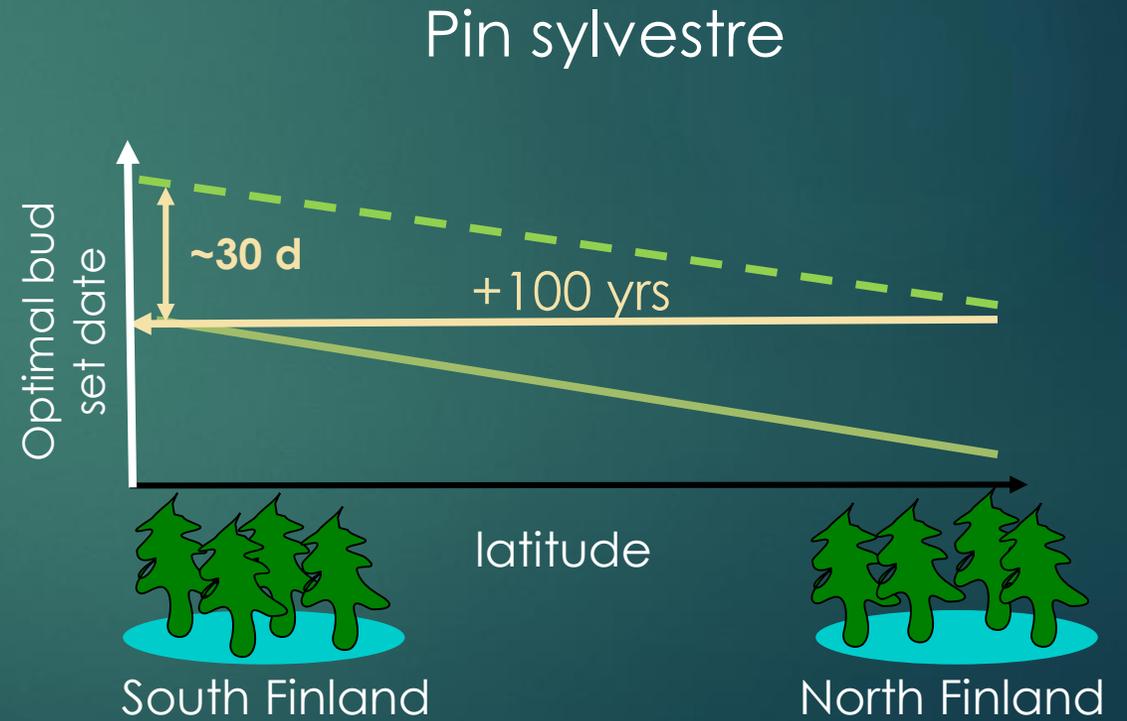
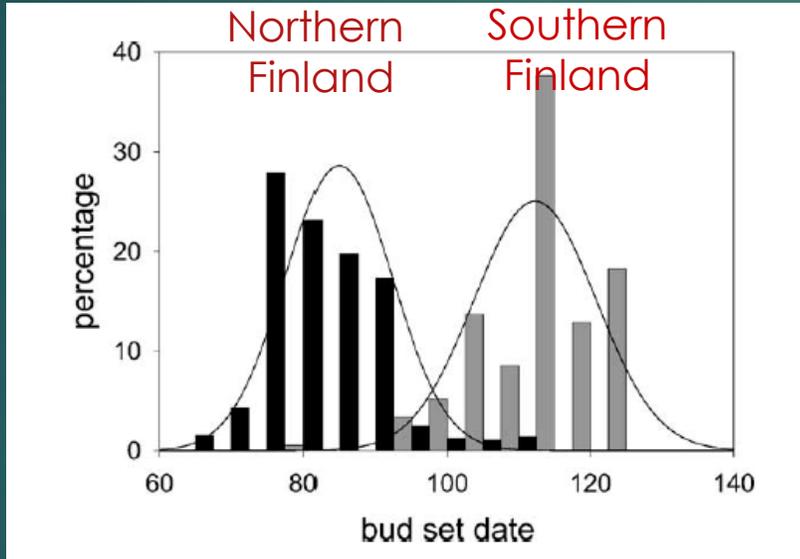
- Les traits qui définissent la niche fondamentale peuvent évoluer sur des pas de temps relativement courts.

Questions : Cette micro-évolution peut-elle permettre un maintien des populations en marge sud ? Ou accélérer la colonisation de nouvelles régions plus au nord ?

Difficulté : Intégrer l'évolution génétique des caractères dans les modèles d'aire de répartition d'espèces...

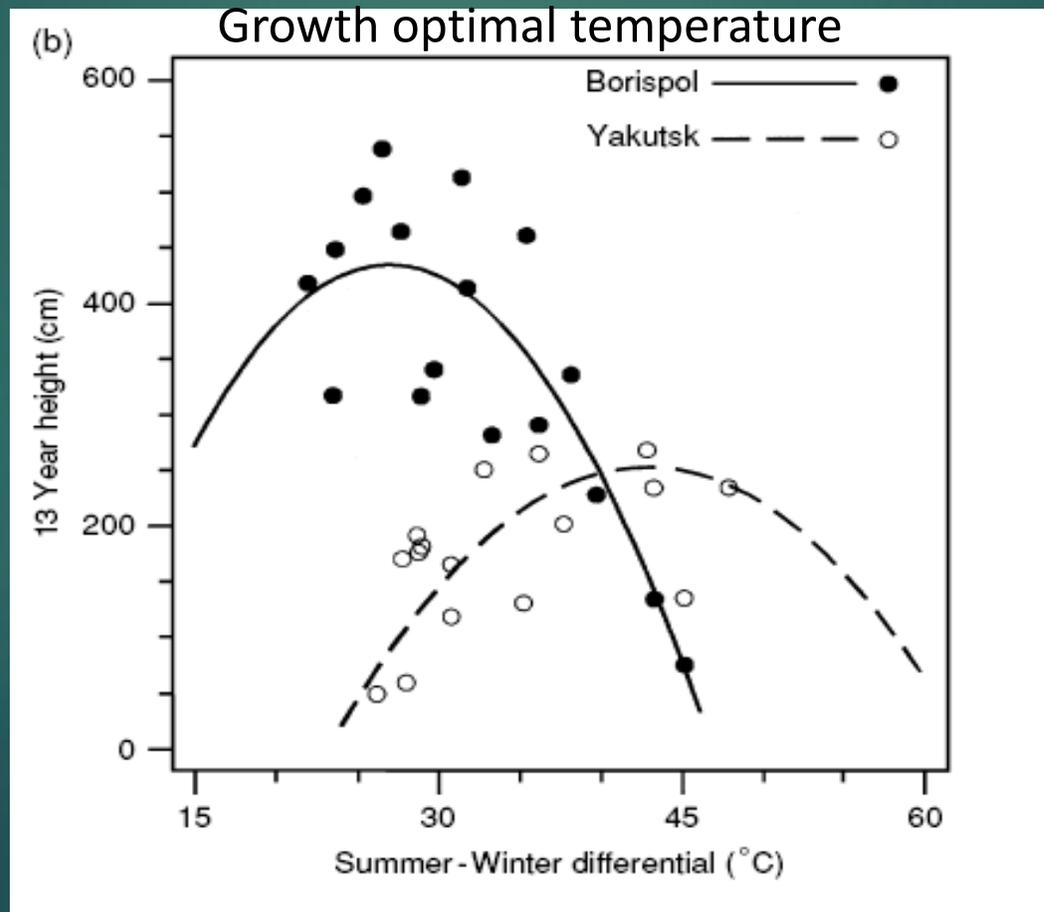
Qu'est ce qui fait évoluer la niche ?

- Climate is a strong selective pressure



Qu'est ce qui fait évoluer la niche ?

- Genetic variability between populations

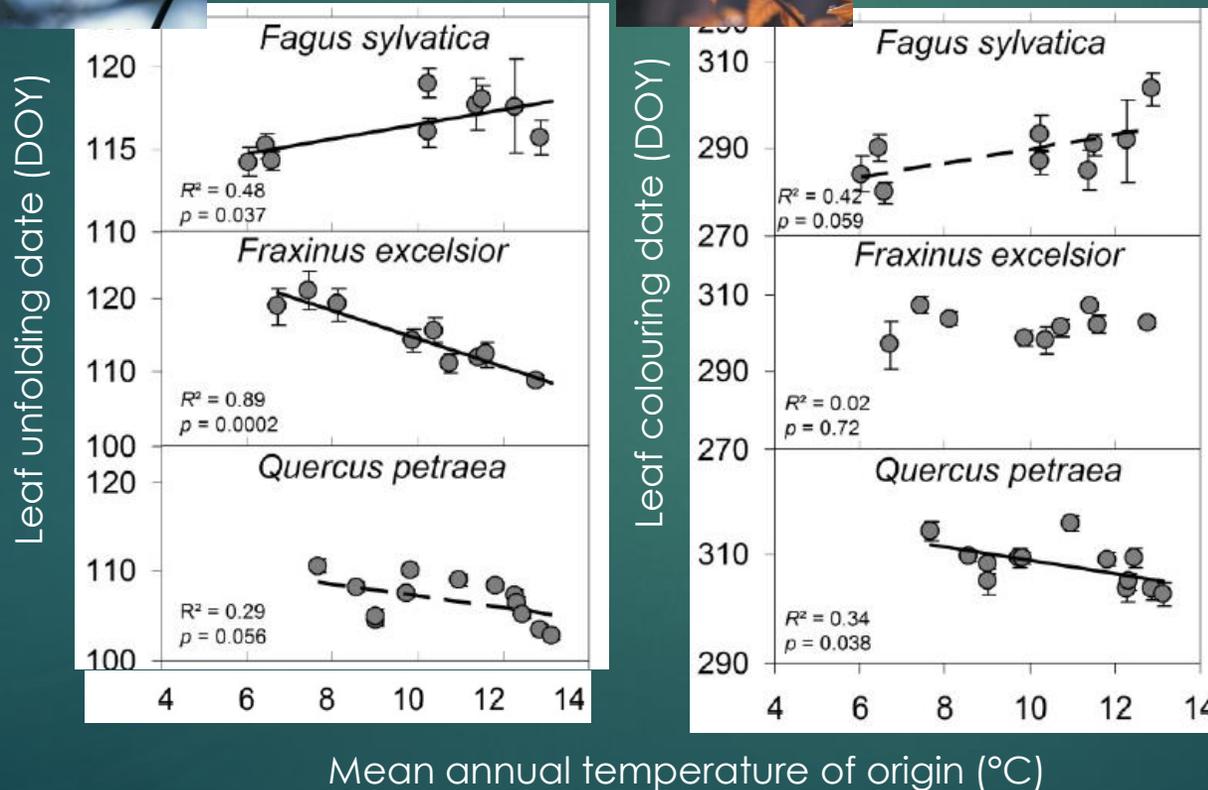


Pin sylvestre



Qu'est ce qui fait évoluer la niche ?

➤ Genetic variability between populations



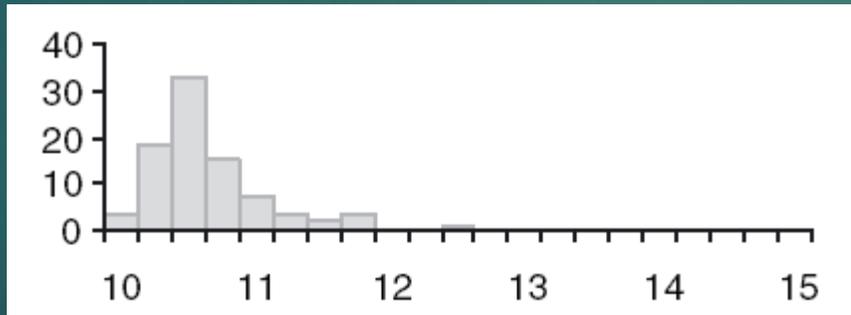
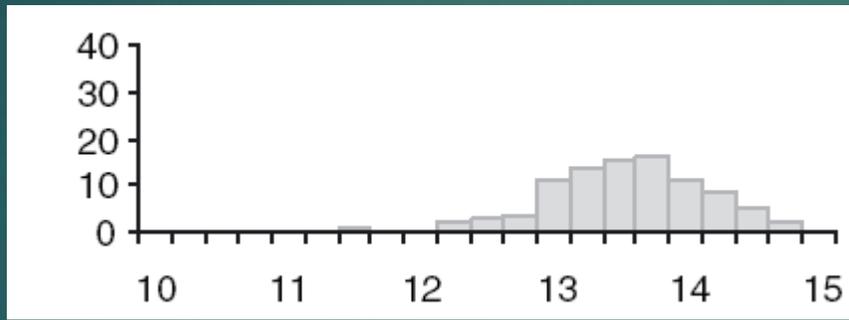
➤ Altitudinal cline (Pyrenees) in leaf unfolding date due to genetic differentiation

Provenances of beech, ash, and sessile oak in a common garden

Qu'est ce qui fait évoluer la niche ?

- Genetic variability within populations

Response to artificial selection of beet flowering date



Critical photoperiod for flowering initiation

10 generations of selection

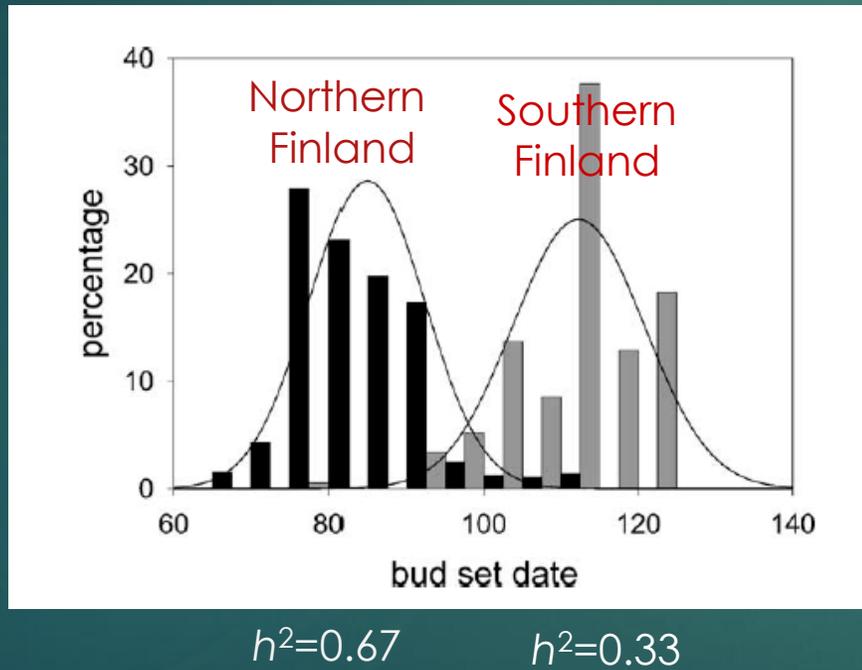


$$h^2 = \frac{\sigma_g^2}{\sigma_p^2} = 0.56$$

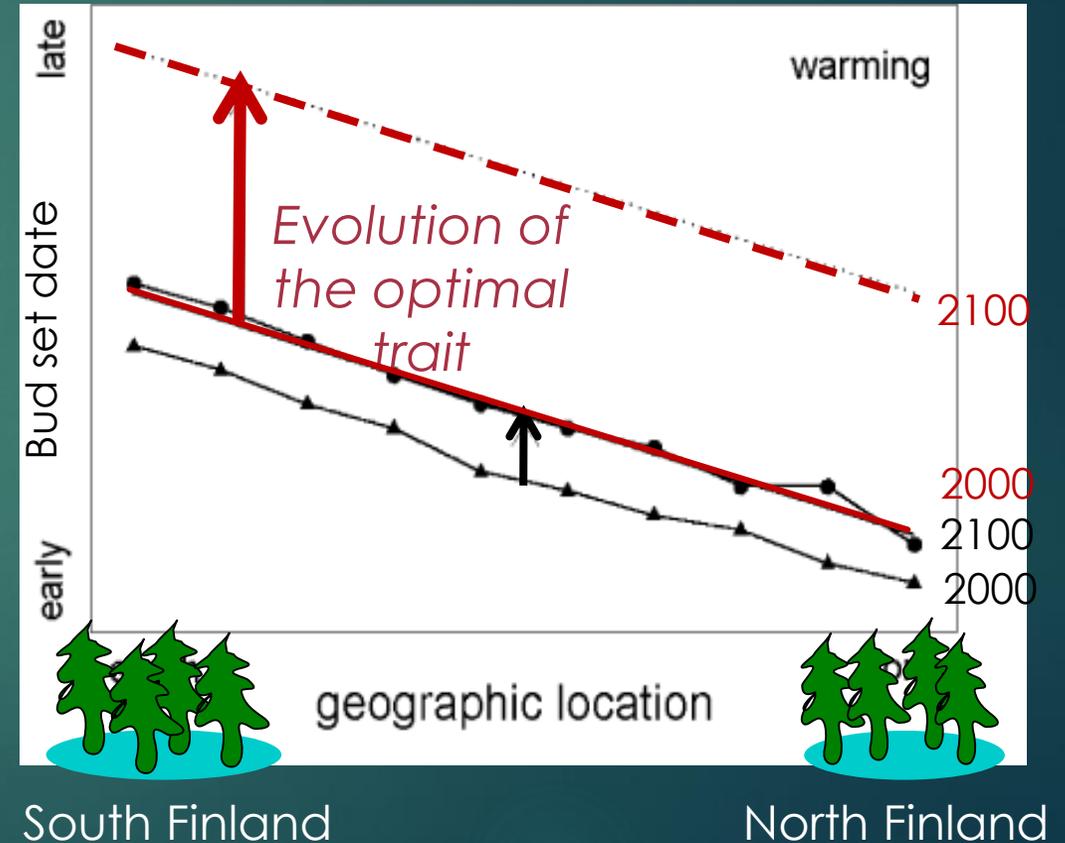
3. Evolution

Qu'est ce qui ralentit l'évolution de la niche ?

- Long generation time



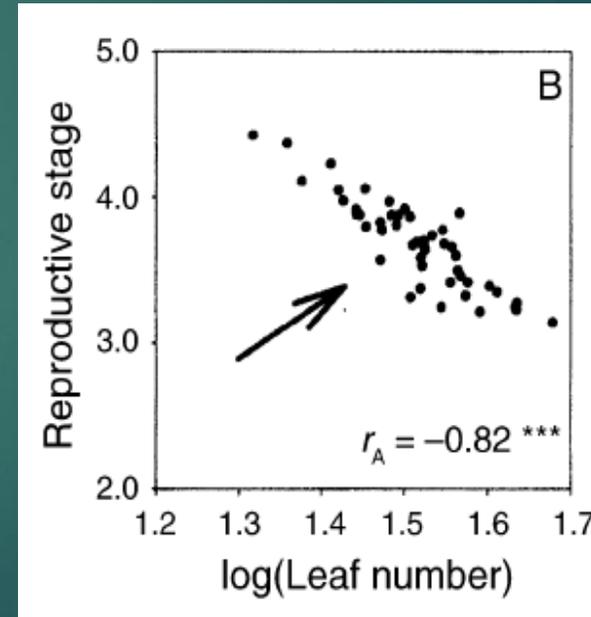
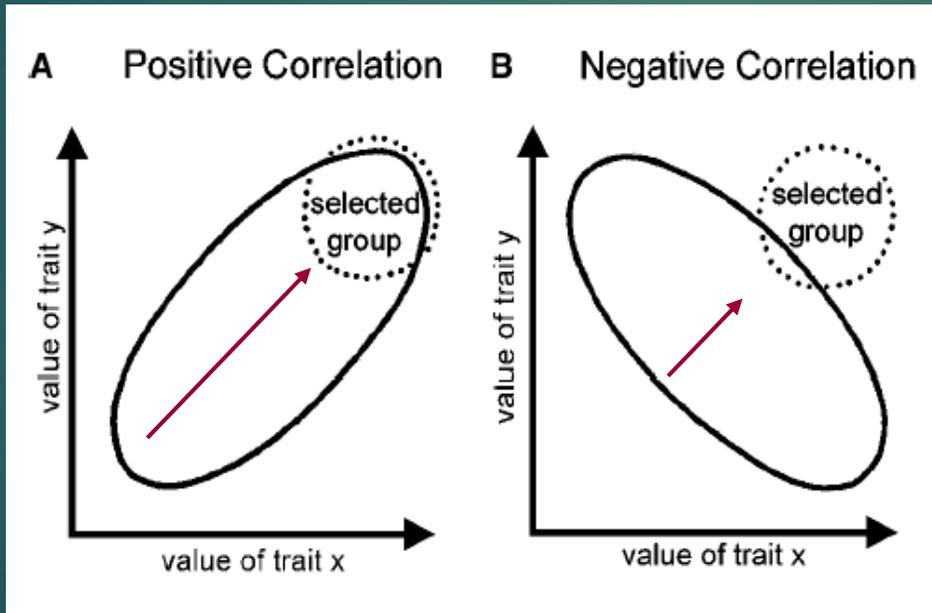
Savolainen et al. For. Ecol.Man.2004



Qu'est ce qui ralentit l'évolution de la niche ?

➤ Genetic correlations

Reinforcing selection Antagonistic selection

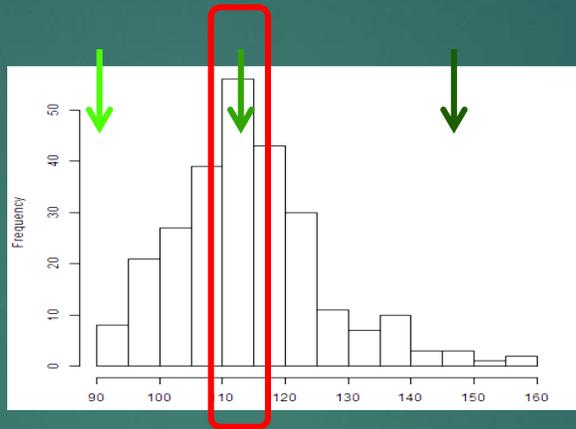


Chamaecrista fasciculata

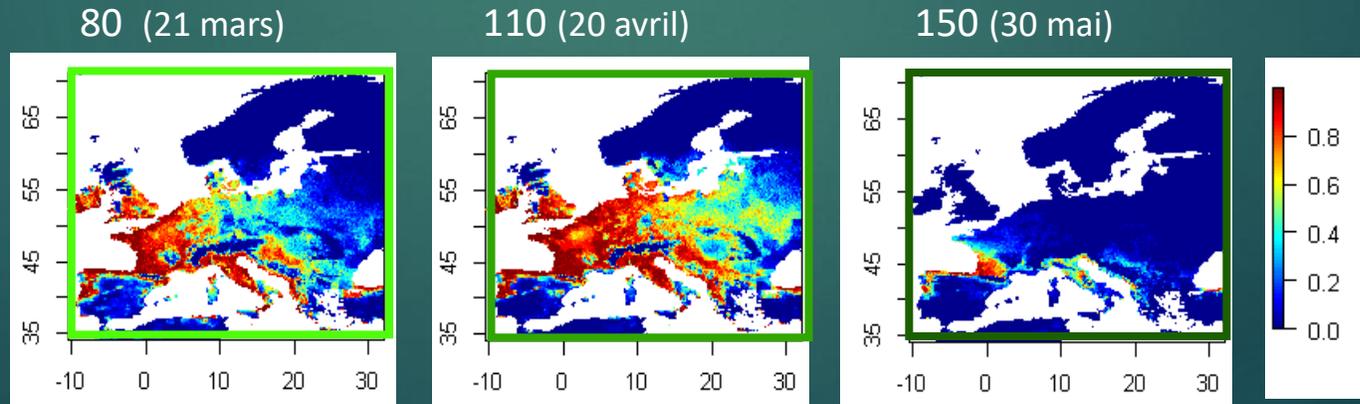
3. Evolution

Estimation des pressions de sélection à l'aide de modèle basés sur les processus

Distribution des dates de feuillaison du chêne pédonculé observées en France

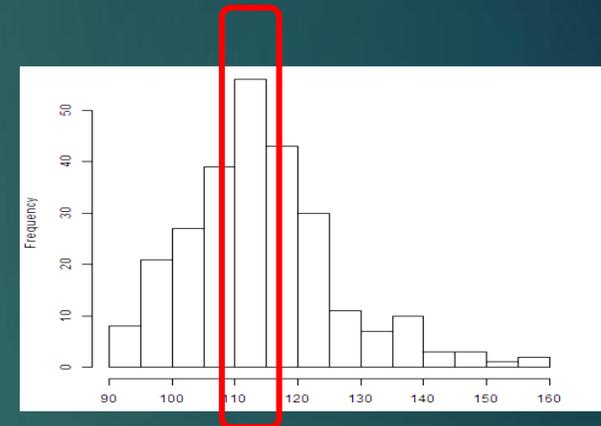
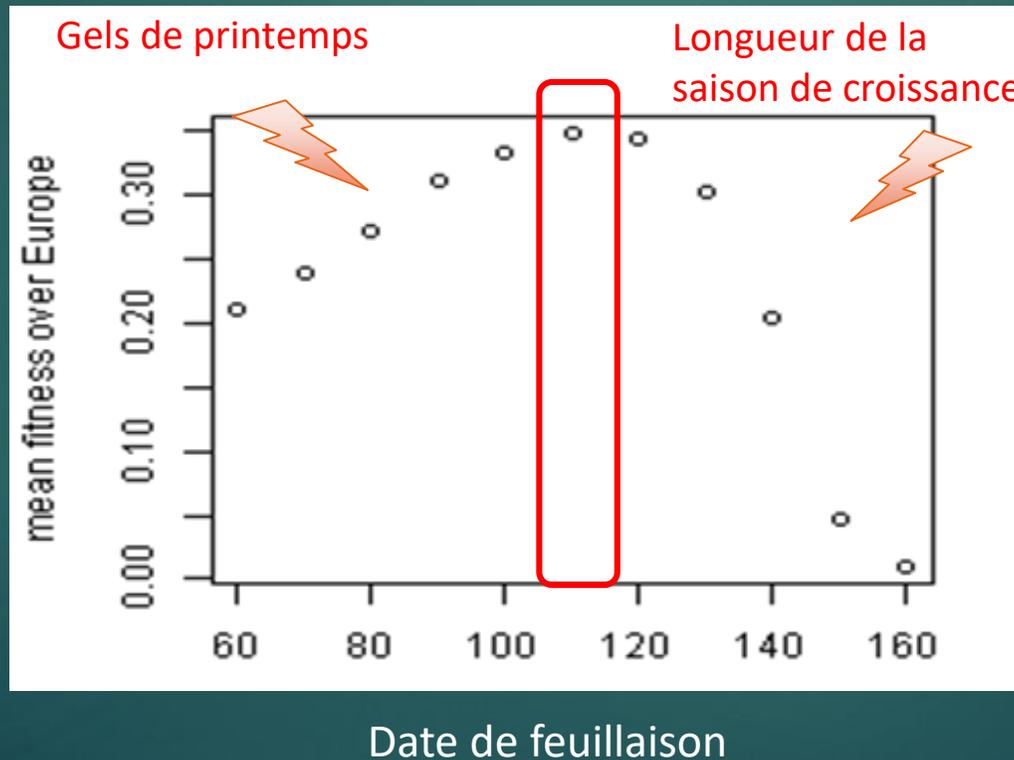


Fitness si date de feuillaison =



Estimation des pressions de sélection à l'aide de modèle basés sur les processus

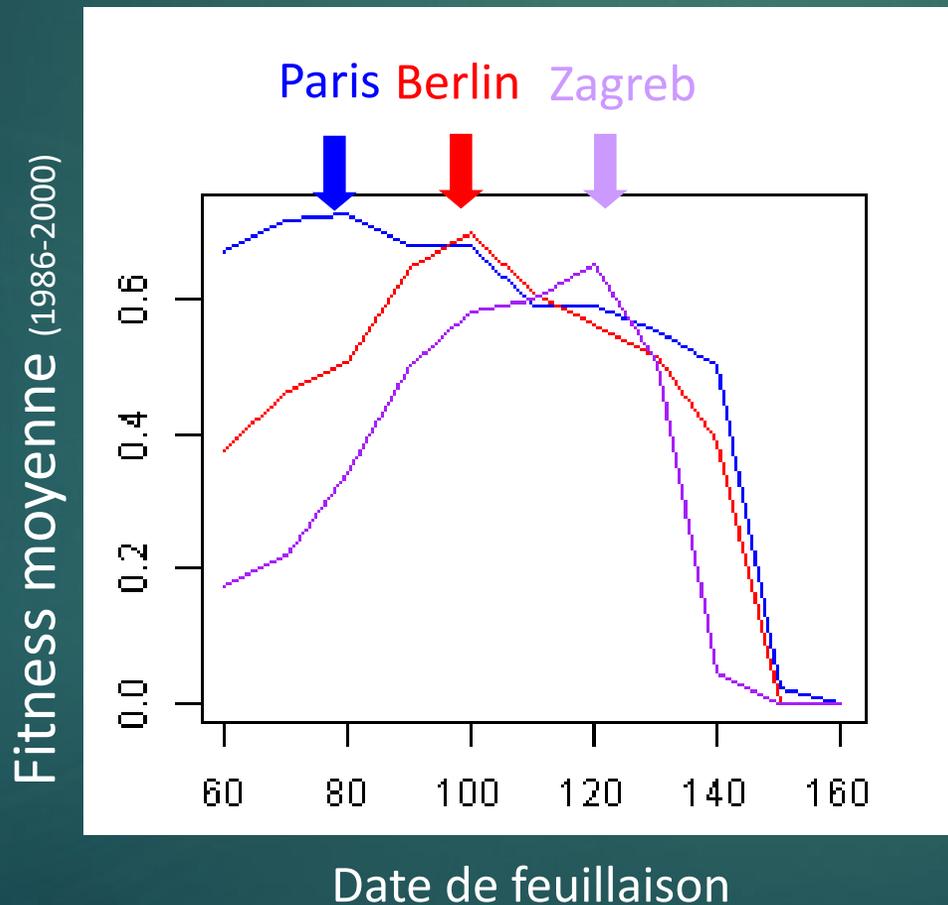
Variation de la fitness moyenne en fonction de la date de feuillaison



➤ Sélection stabilisante asymétrique sur la date de feuillaison

3. Evolution

Estimation des pressions de sélection à l'aide de modèle basés sur les processus

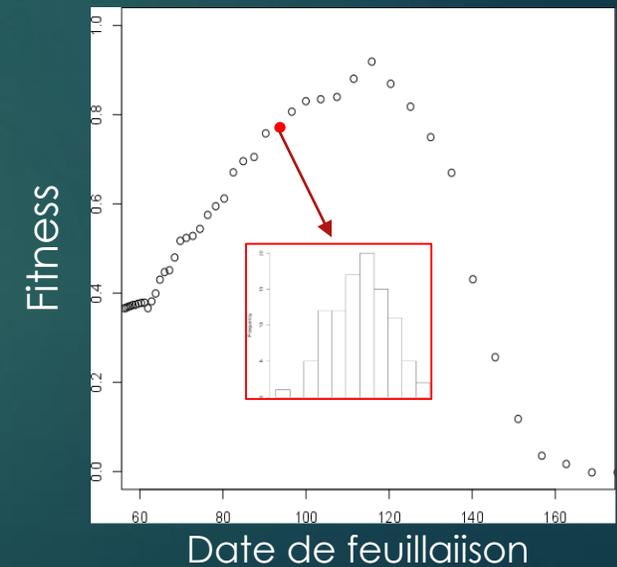


➤ La valeur du trait optimale et la force de la sélection varient dans l'espace.

Estimation des pressions de sélection à l'aide de modèle basés sur les processus

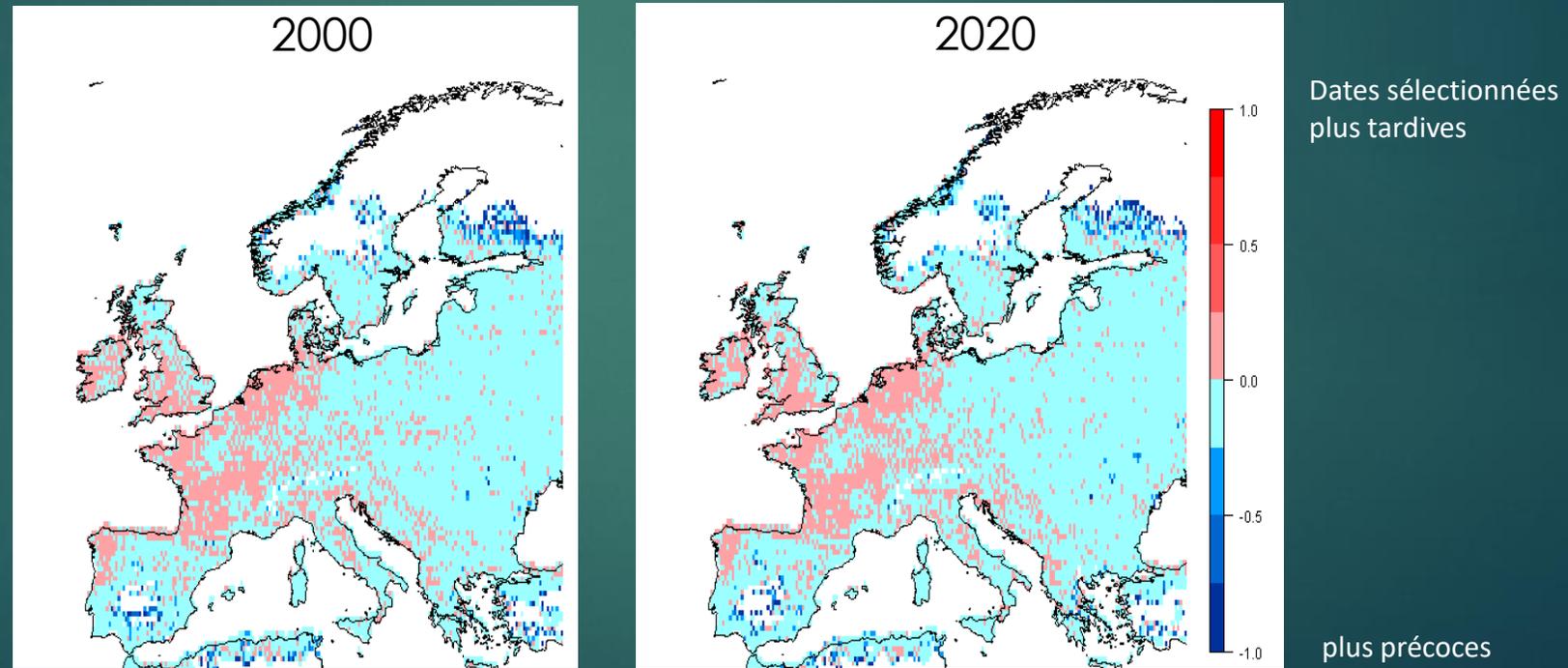
Estimation des gradients de sélection sur le trait

1. On simule les valeurs de fitness pour toute la gamme de valeurs de trait possible
2. Pour chaque valeur de trait, on considère une population polymorphe dont la valeur de trait moyen est cette valeur de trait et de variance égale à ce qui est observée *in natura*
3. On calcule le coefficient de sélection comme
$$\beta = ((\bar{w}' - \bar{w}) / \delta_T / \bar{w}) \cdot \sigma_T$$



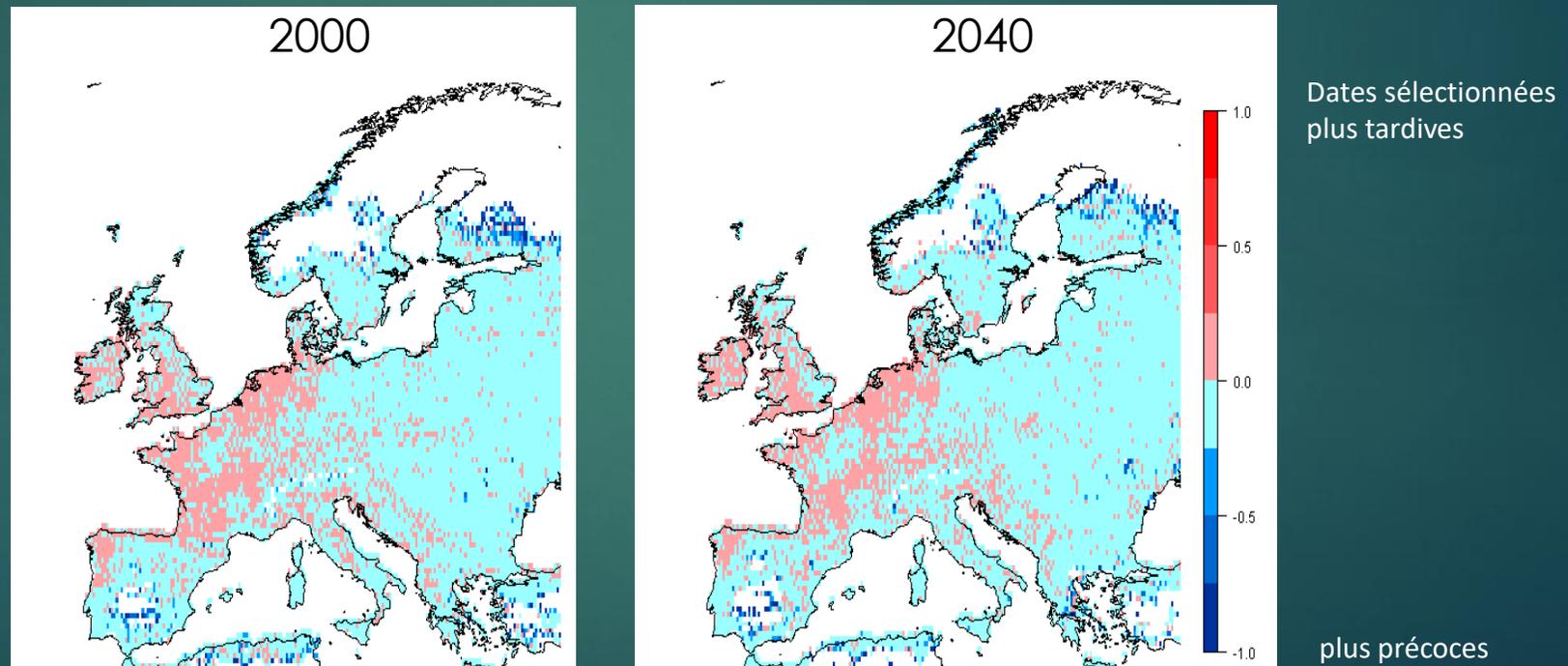
Quelle est la sélection à l'échelle de l'aire de répartition ?

Gradients de sélection sur la date de feuillaison du hêtre



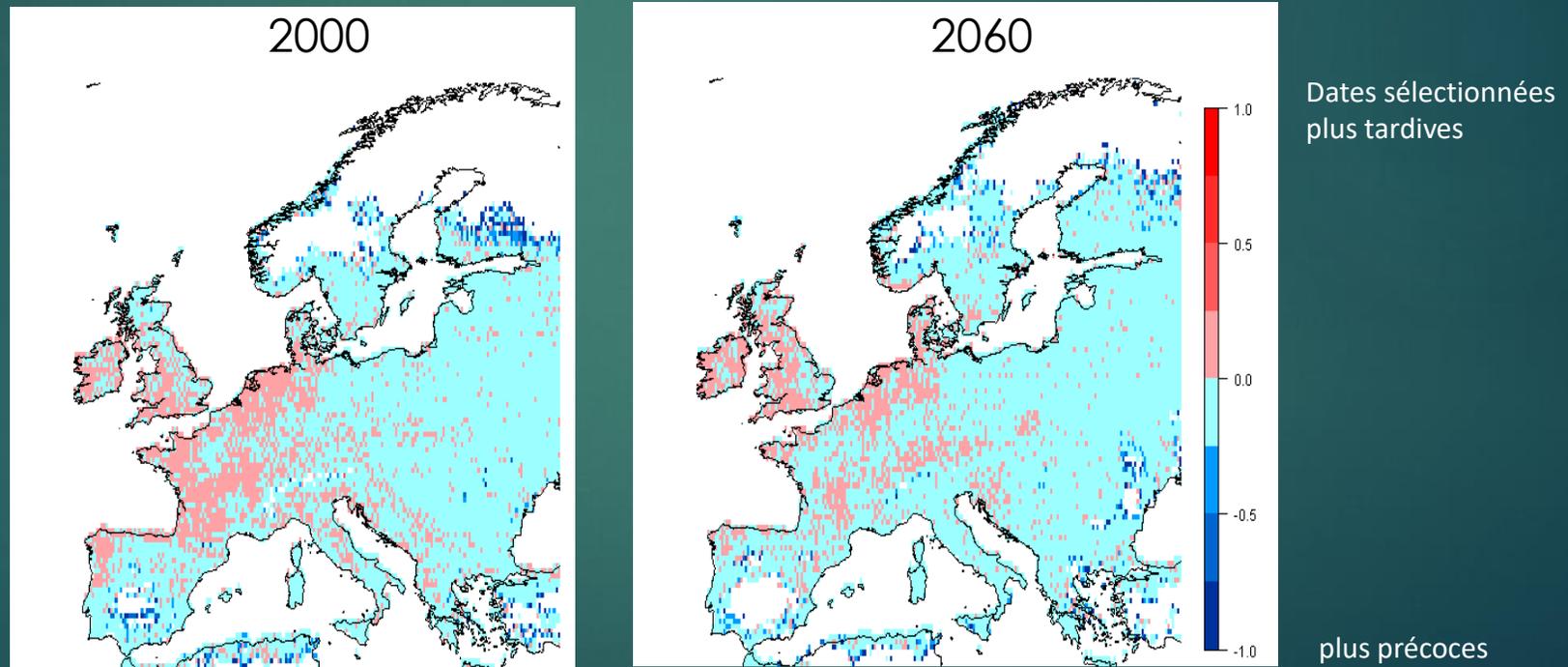
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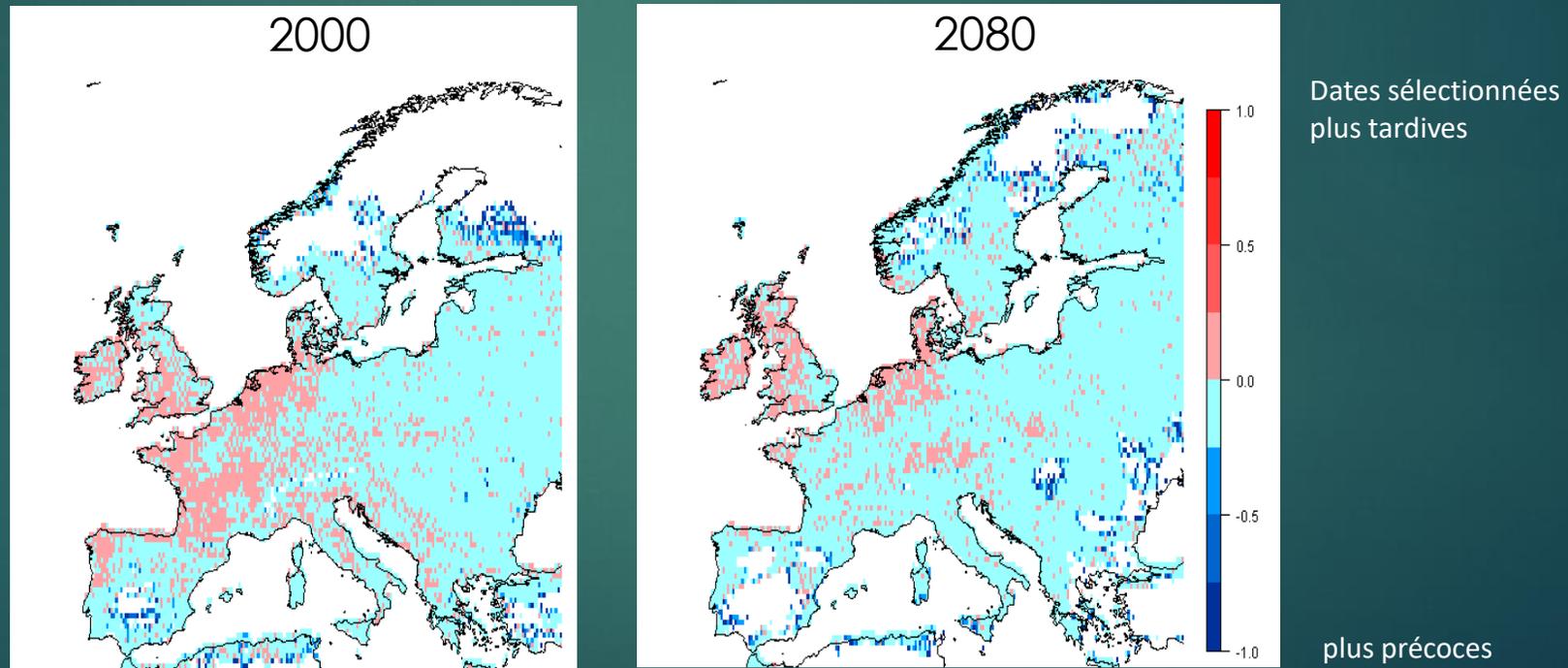
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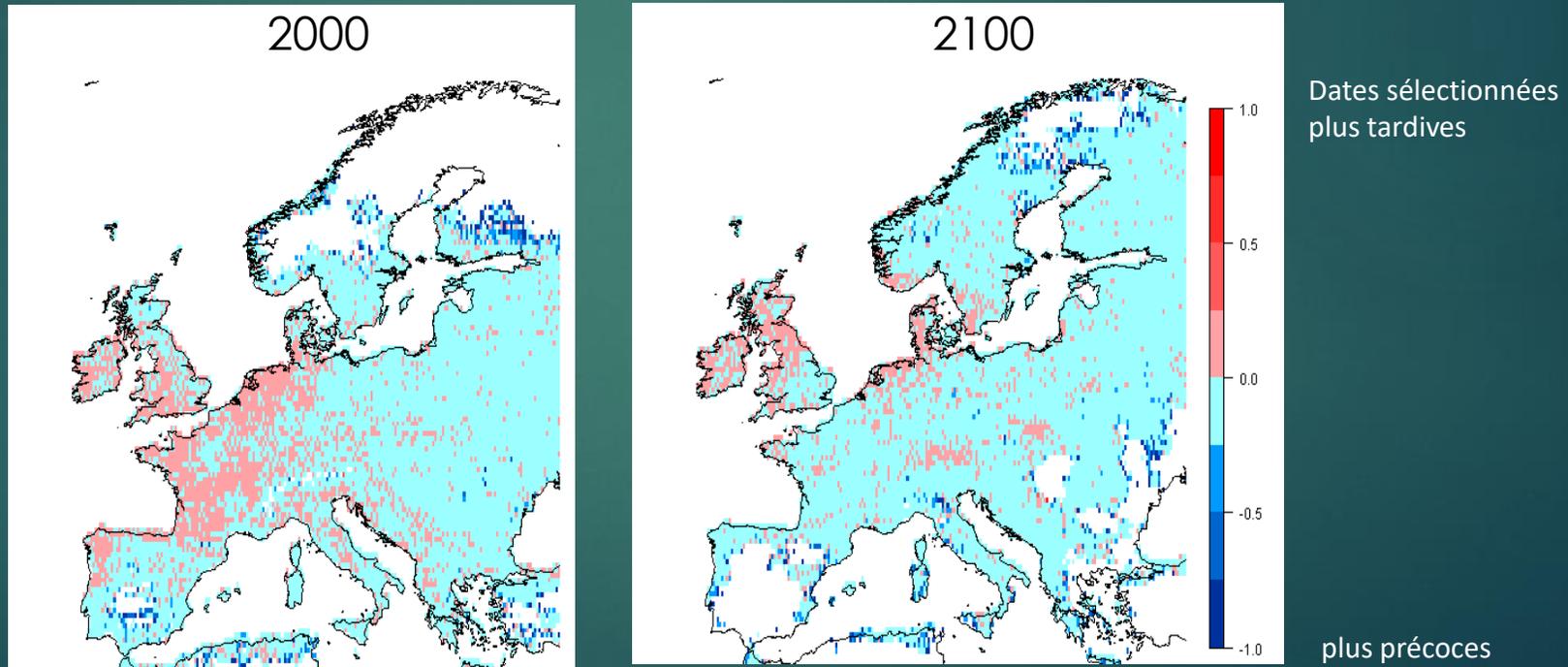
Quelle est la sélection à l'échelle de l'aire de répartition ?

Gradients de sélection sur la date de feuillaison du hêtre



Quelle est la sélection à l'échelle de l'aire de répartition ?

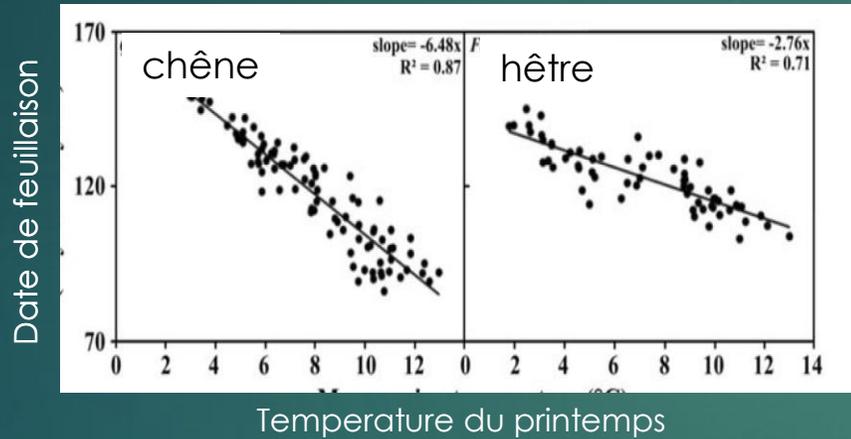
Gradients de sélection sur la date de feuillaison du hêtre



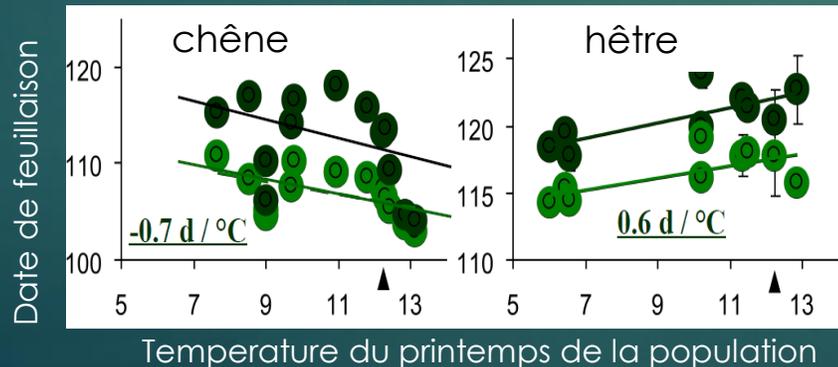
3. Evolution

Quelle est la sélection à l'échelle d'une vallée ?

10 années de suivi des dates de feuillaison in situ

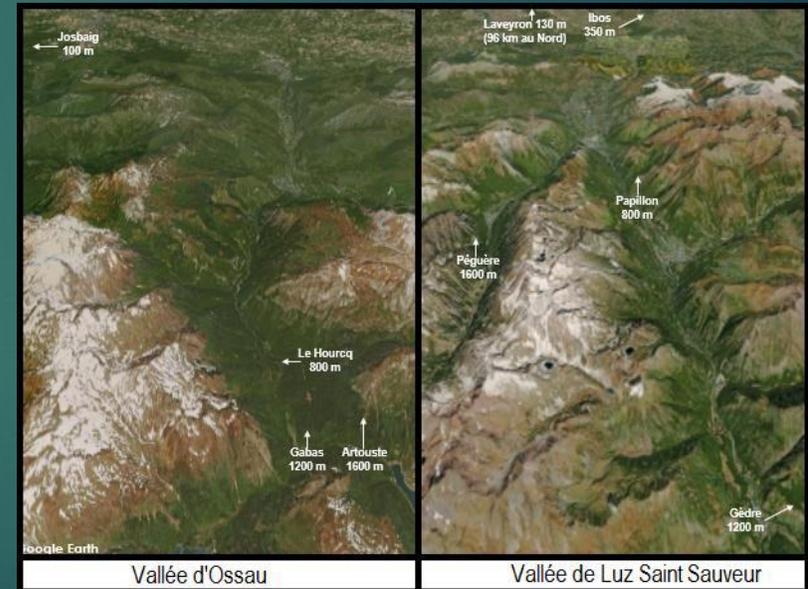


Suivis des populations dans 2 jardins commun commun



2 vallées dans les Pyrénées françaises
5 populations/vallée

100 m
1600 m

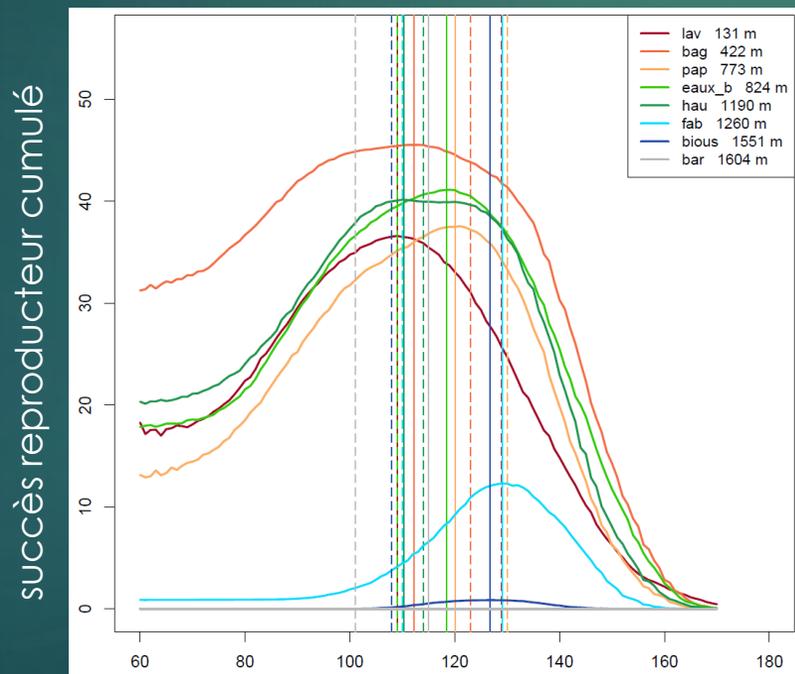


12.8 °C
6.7 °C

Quelle est la sélection à l'échelle d'une vallée ?

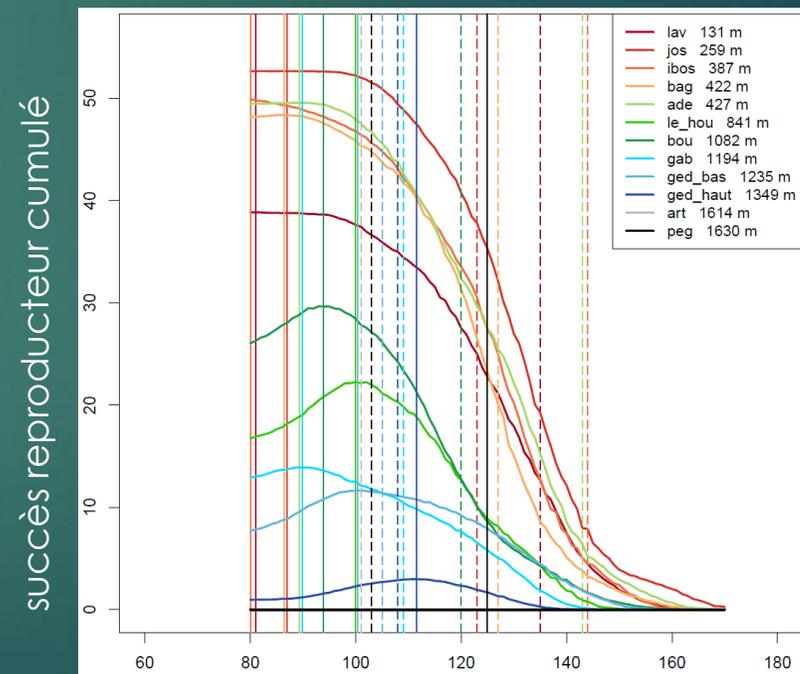
Paysage adaptatif et dates de feuillaison optimales

Hêtre



Date de feuillaison

Chêne



Date de feuillaison

— Date optimale

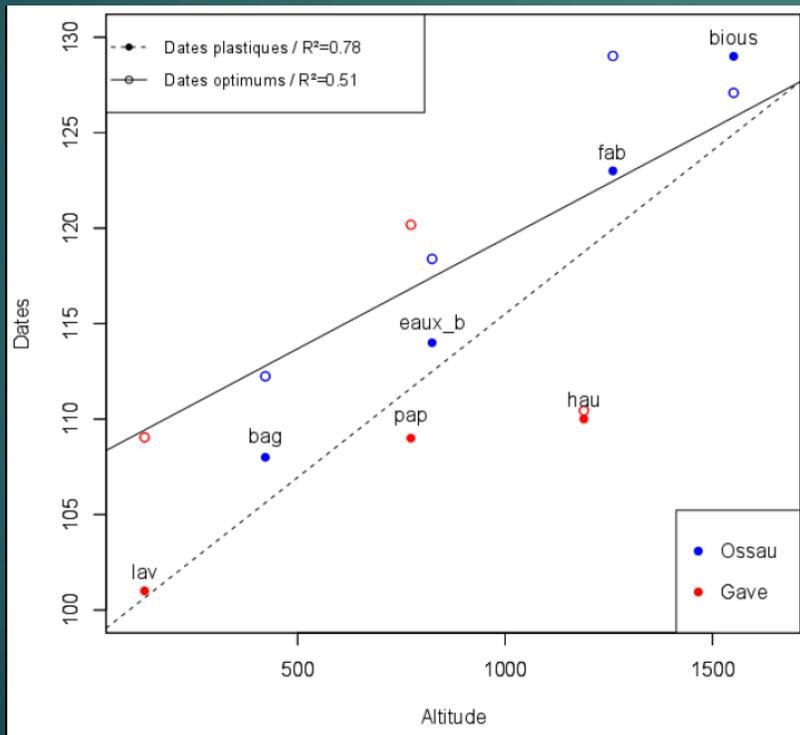
.....

Date moyenne de la population

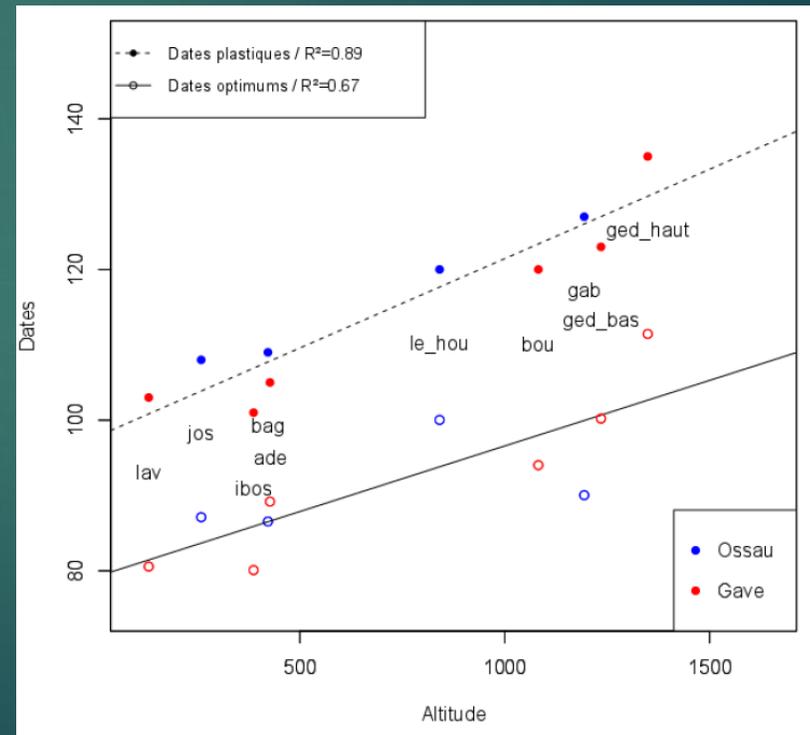
Quelle est la sélection à l'échelle d'une vallée ?

Ecart entre date optimale et date réalisée

Hêtre



Chêne



The background features a teal-colored gradient with several semi-transparent DNA double helix structures. A solid red vertical bar is positioned in the top right corner.

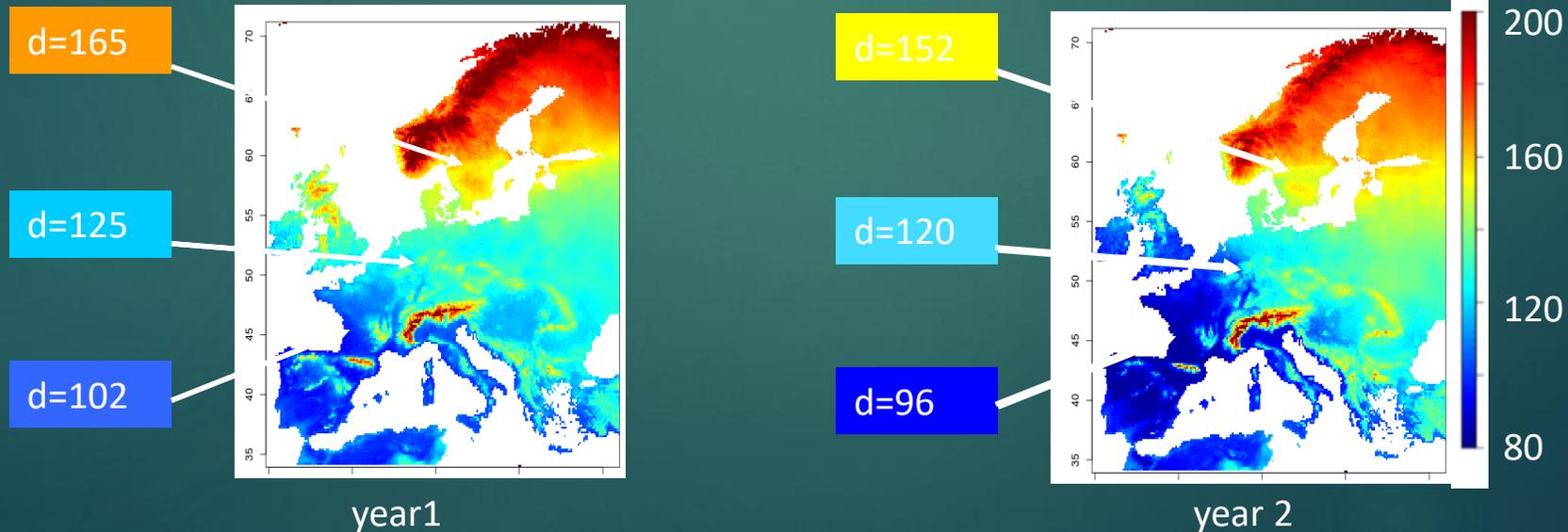
Merci de votre attention

What is the effect of plasticity on range size and niche breadth?

Method: suppress plasticity of phenological dates with temperature

Model 0

Plastic populations



What is the effect of plasticity on range size and niche breadth?

Method: suppress plasticity of phenological dates with temperature

Model 1

Non plastic populations
Phenological dates are fixed to their local average



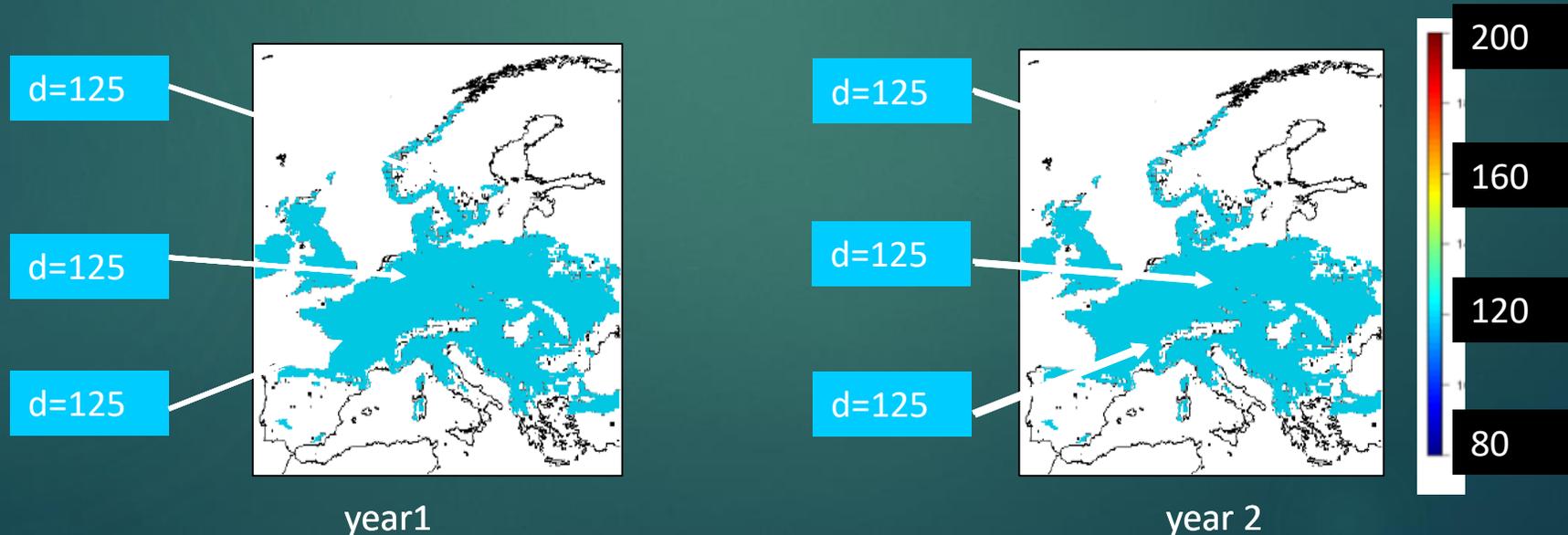
What is the effect of plasticity on range size and niche breadth?

Method: suppress plasticity of phenological dates with temperature

Model 2

Non plastic populations

Phenological dates are fixed to their rangewide period average



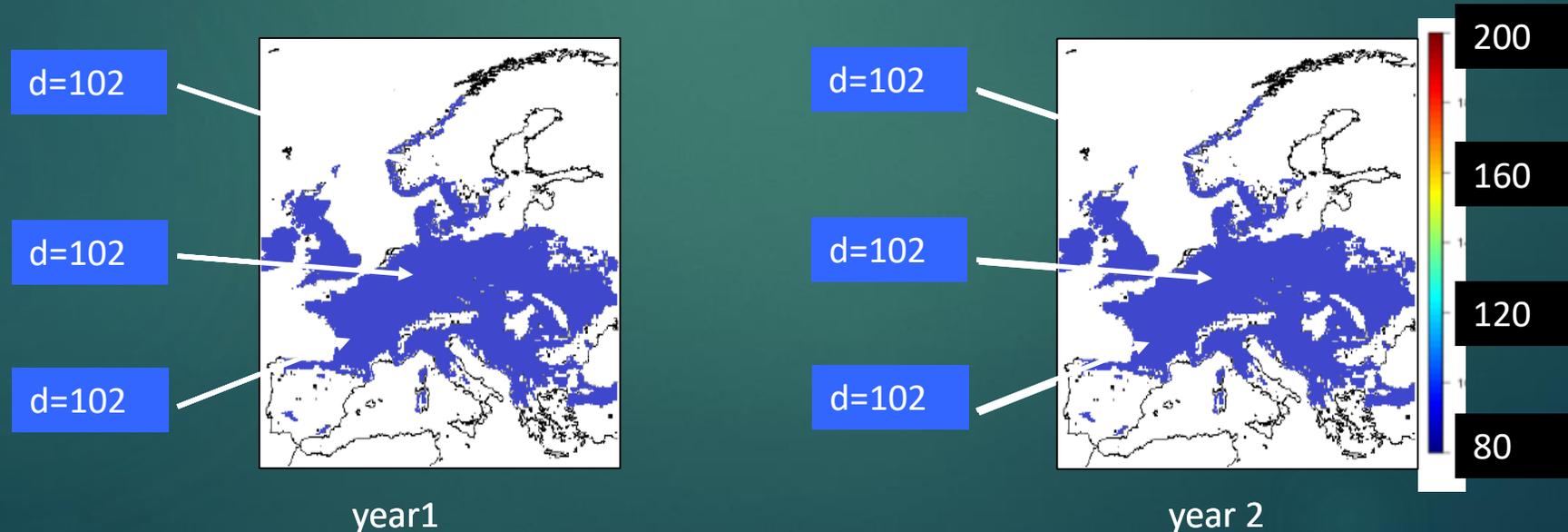
What is the effect of plasticity on range size and niche breadth?

Method: suppress plasticity of phenological dates with temperature

Model 3

Non plastic populations

Phenological dates are fixed to their rangewide 1981-2000 average



Disentangling the different effects of plasticity

Source of variation :	Year-to-year	Spatial	Trend
Model 0: Reference model with empirically fitted reaction norms Dates of spring and fall events vary with locality and across years.	✓	✓	✓
Models 1: Testing for the effect of year-to-year fluctuations Dates of spring, fall, or spring & fall events are <i>forced to their local period average</i> .	⊘	✓	✓
Models 2: Testing for the effect of spatial variation Dates of spring, fall, or spring & fall events are <i>forced to their rangewide period average</i> .	-	X	X
	⊘	⊘	✓
	⊘	⊘	⊘
Models 3: Testing for the effect of trend variation Dates of spring, fall, or spring & fall events are <i>forced to their rangewide 1981-2000 average</i> .	-	-	-

The case of beech, sessile oak and Scots pine



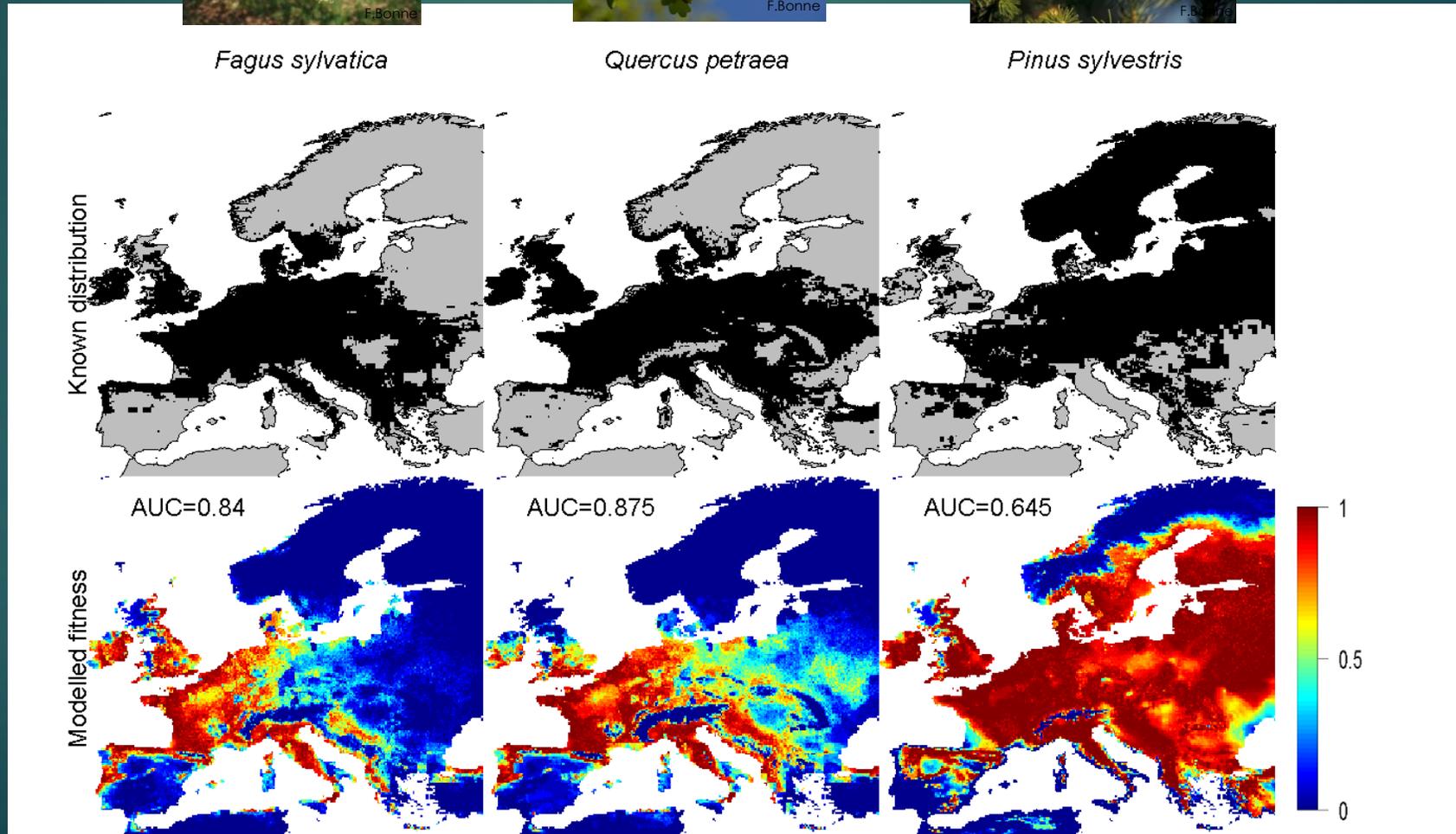
Fagus sylvatica



Quercus petraea



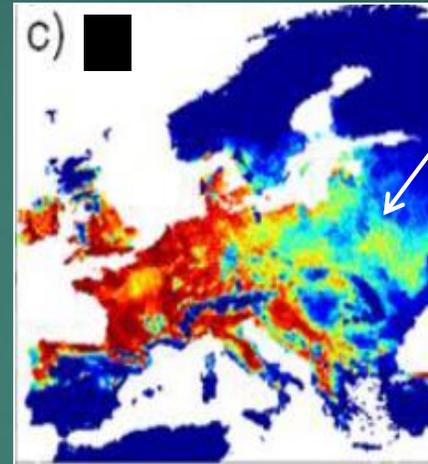
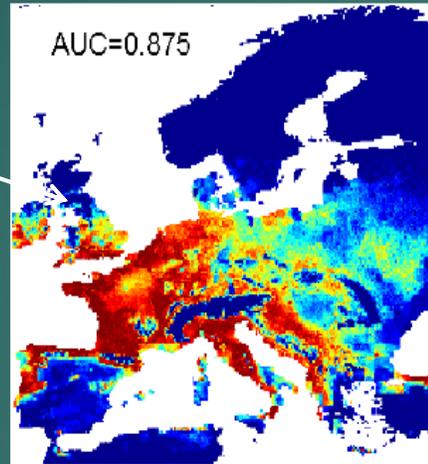
Pinus sylvestris



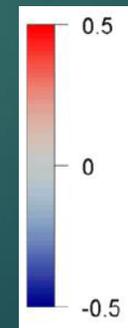
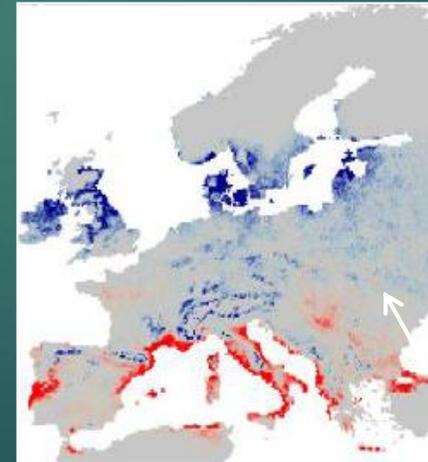
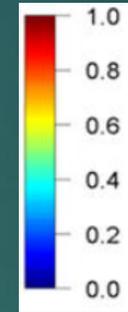
Some keys to read the results

In the geographic space

Fitness map when dates varies with location and across years (Model 0)



Fitness map when dates are fixed = Loss of plasticity



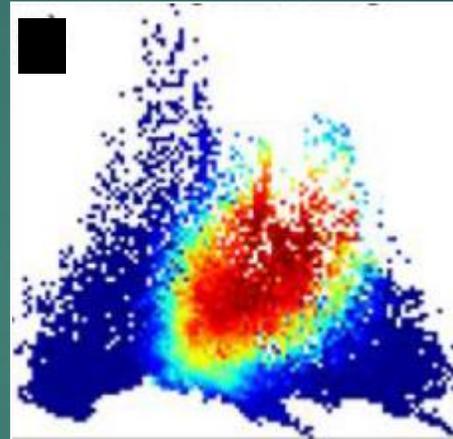
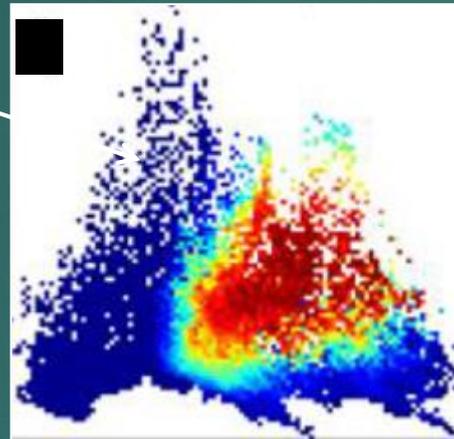
plasticity advantage
plasticity disadvantage

Effect of plasticity on fitness

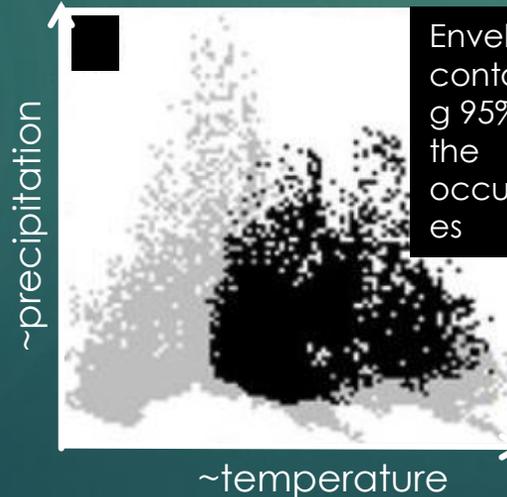
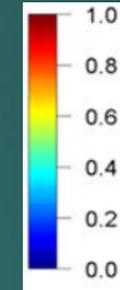
Some keys to read the results

In the climatic space

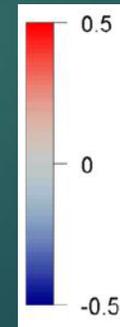
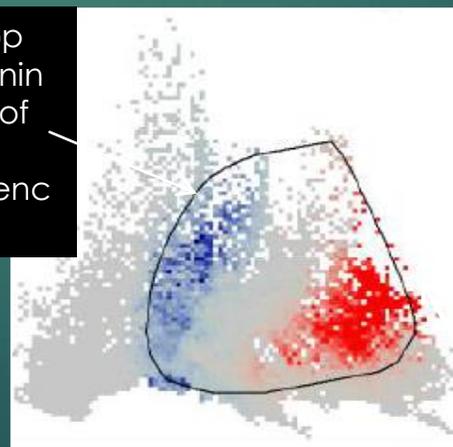
Fitness map when dates varies with location and across years (Model 0)



Fitness map when dates are fixed = Loss of plasticity



Envelop containing 95% of the occurrences

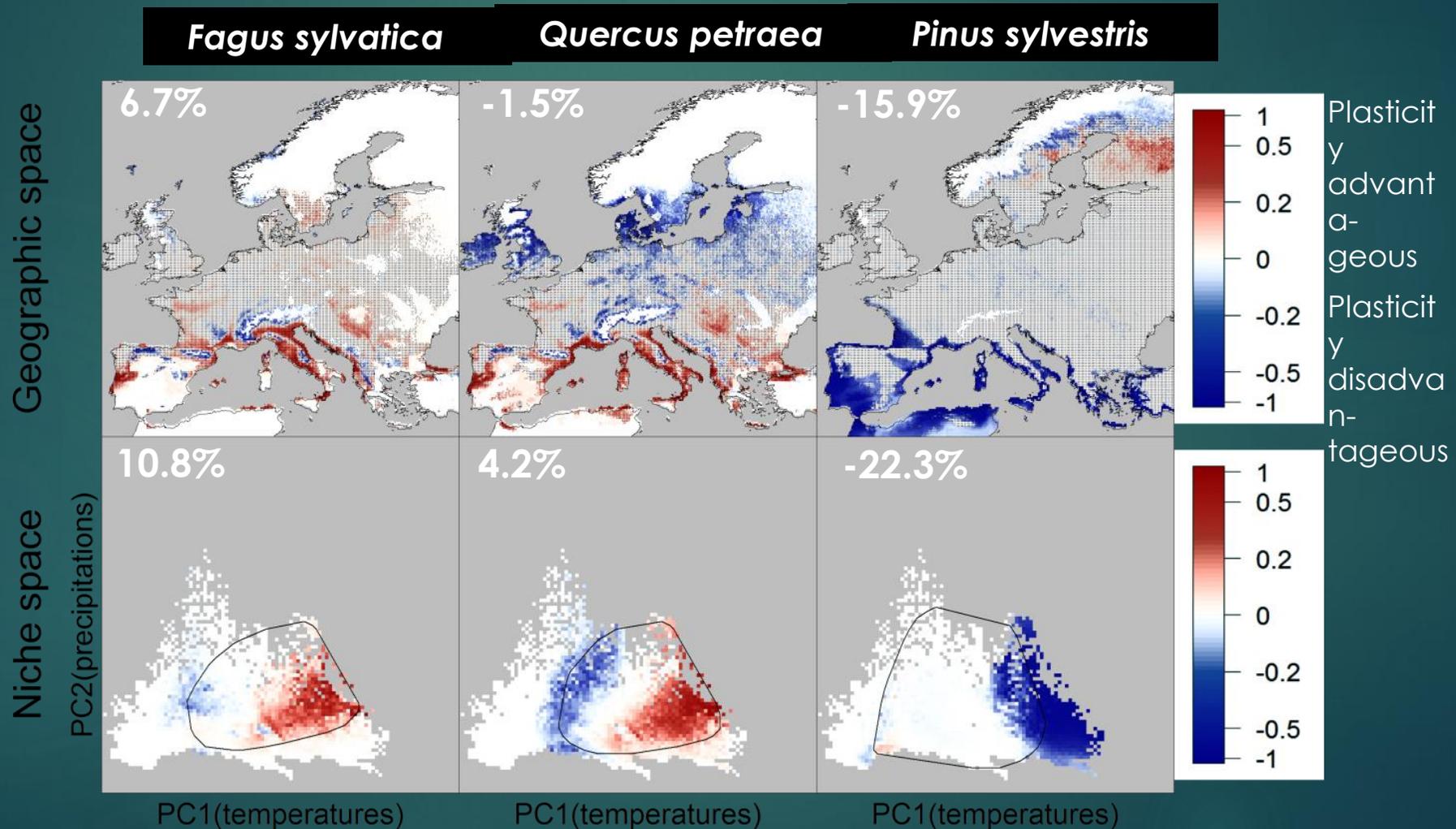


plasticity advantage
0
plasticity disadvantage

Effect of plasticity on fitness

Is plasticity adaptive in current conditions?

Model 0 (plastic) – Model 2 (fixed to rangewide average)



Is plasticity adaptive in current conditions?

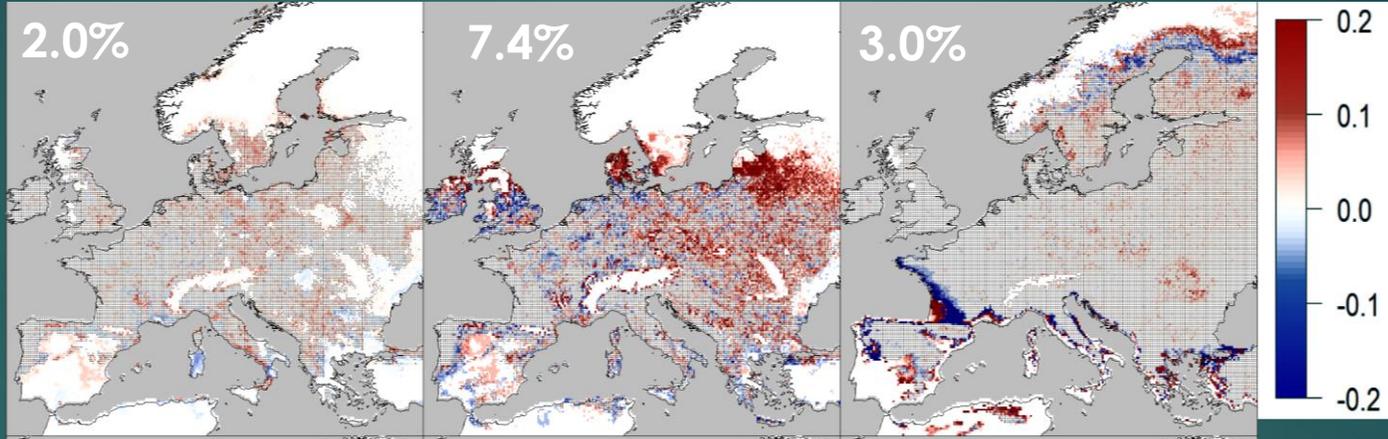
Fagus sylvatica

Quercus petraea

Pinus sylvestris

Model 0 (plastic) – Model 1 (fixed to local average)

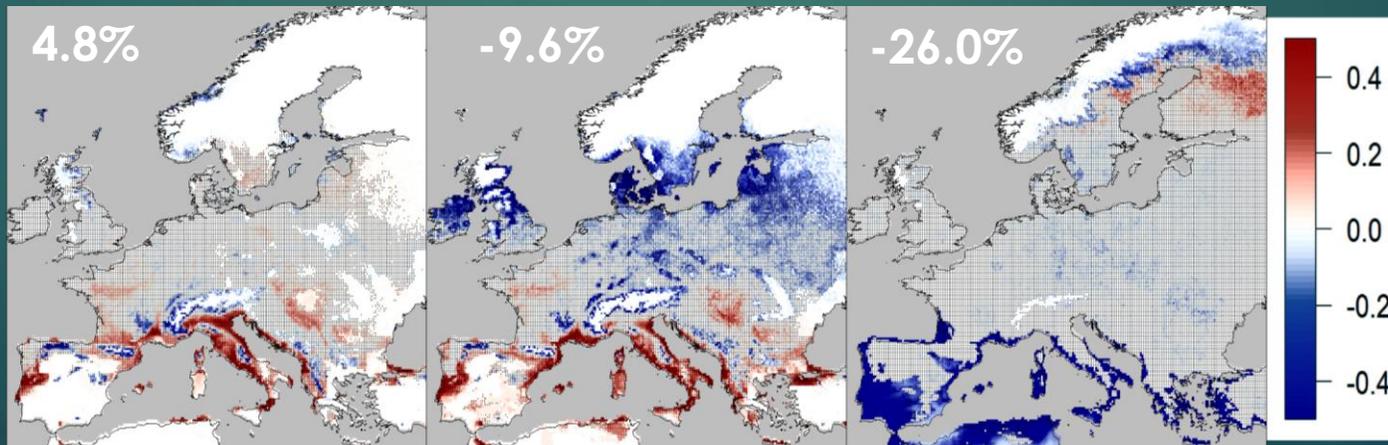
Advantage of interannual variation



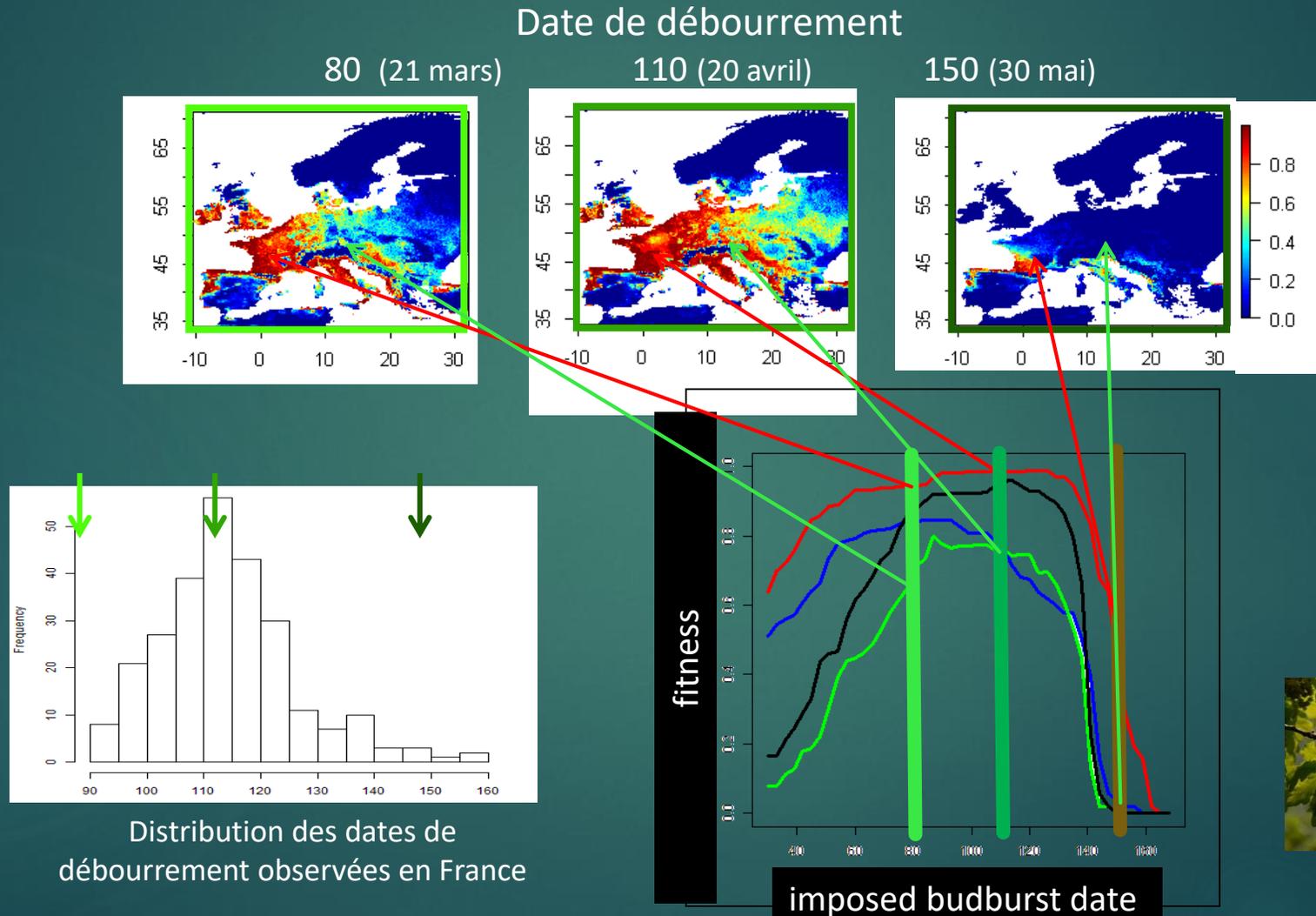
Plasticity advantage
Plasticity disadvantageous

Model 1 (fixed to local average) – Model 2 (fixed to rangewide average)

Further advantage of geographic variation

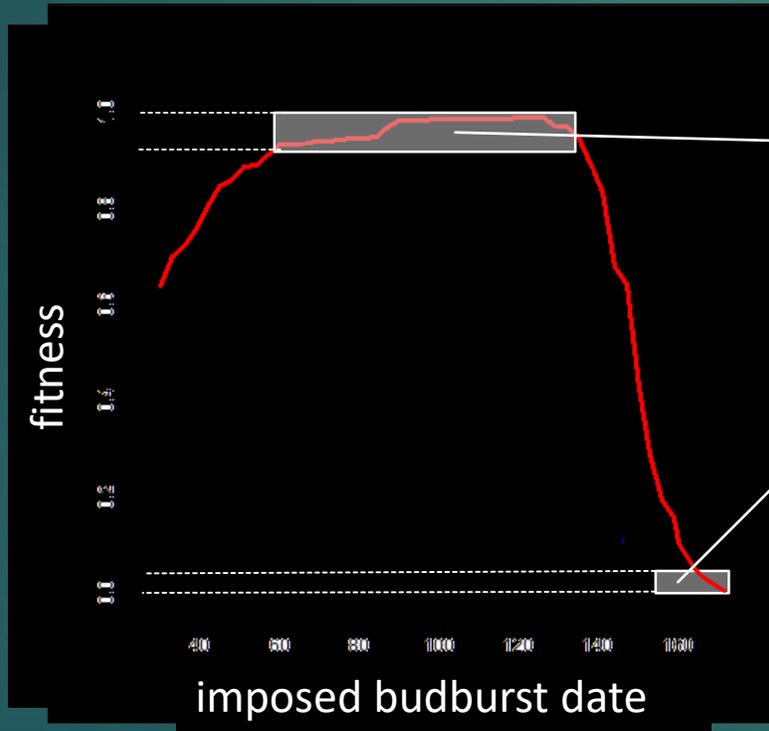


Why is interannual effect of plasticity so weak?

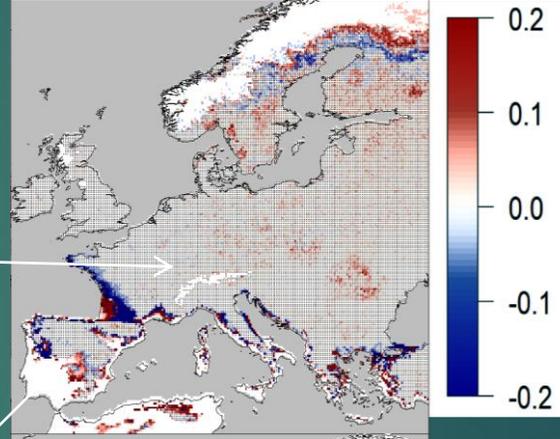


What's going on at the margins?

Pinus sylvestris

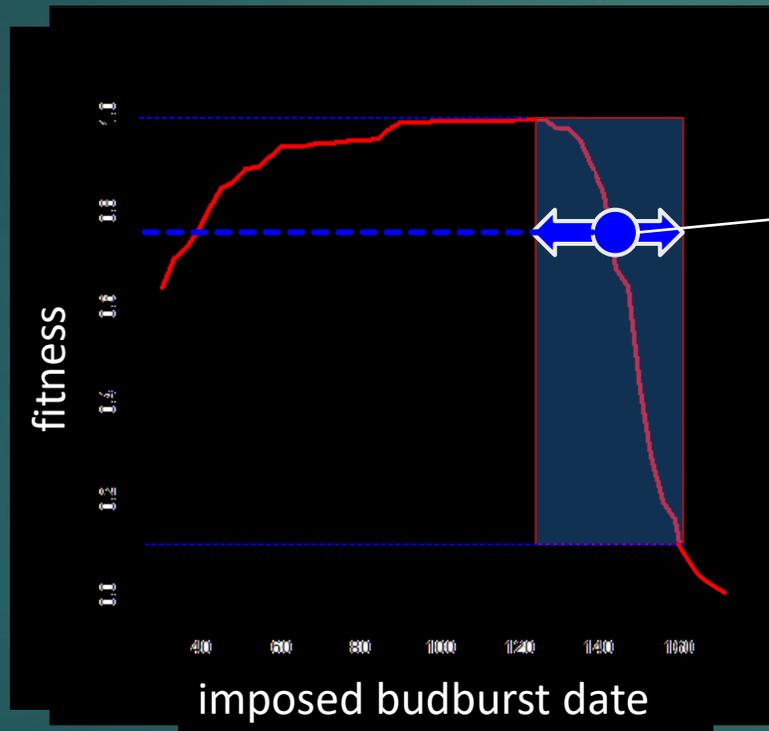


Advantage of interannual variation



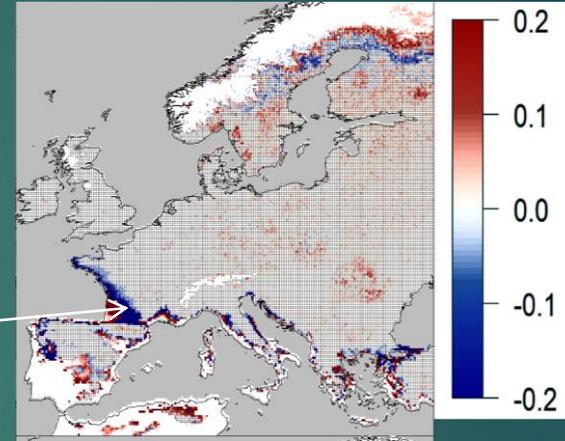
0.2 Plasticity advantage
0.1
0.0
-0.1 Plasticity disadvantage
-0.2

What's going on at margins?



Pinus sylvestris

Advantage of
interannual variation

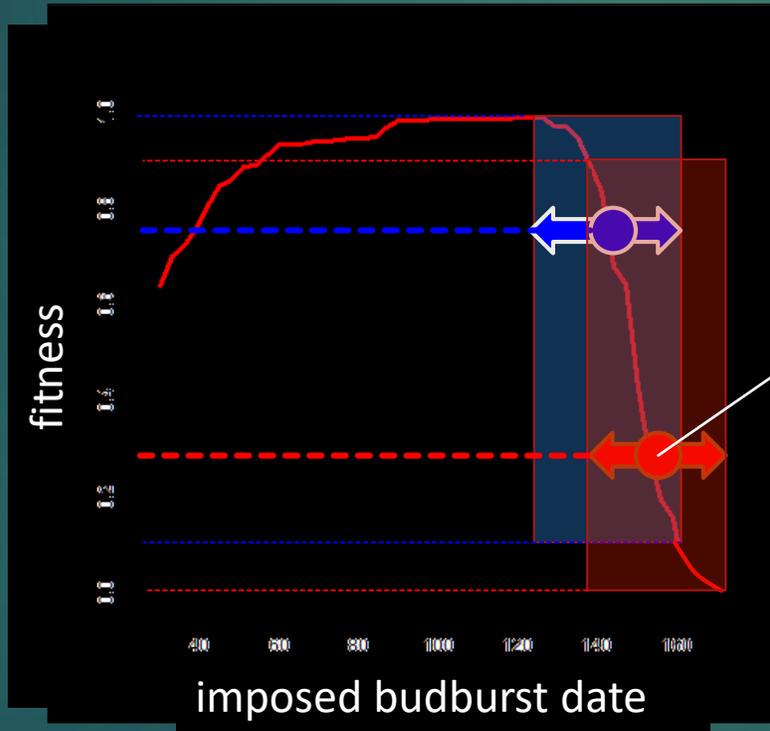


0.2
0.1
0.0
-0.1
-0.2

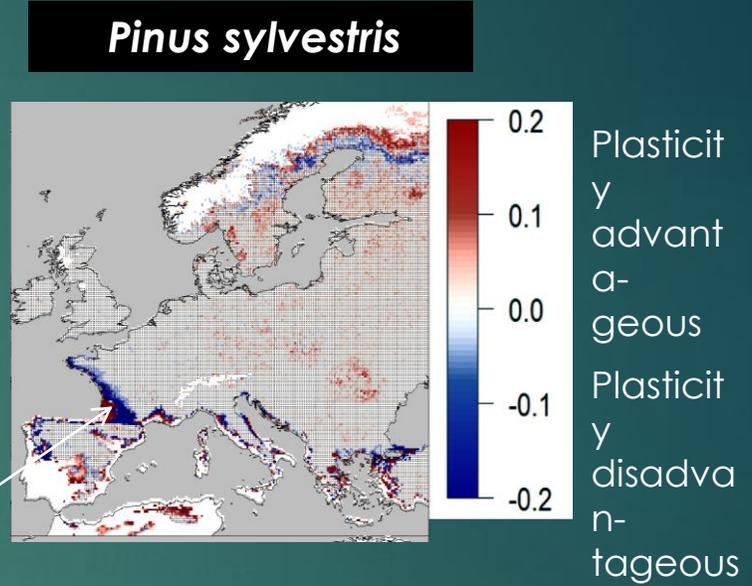
Plasticity
advantageous

Plasticity
disadvantageous

What's going on at the margins?



Advantage of interannual variation



Is plasticity adaptive in future conditions?

➤ Plasticity is more advantageous in future than current conditions in deciduous species

	1981-2000	1981-2000	1981-2000
	Range change		
Year-to-year (1/0)	2.0%	7.4%	3.4%
Spatial (1-2/1)	4.8%	-9.6%	-19.9%
Trend (1-3/2)	-	-	-
All effects (1-3/0)	6.7% <	-1.5% <	-15.9%

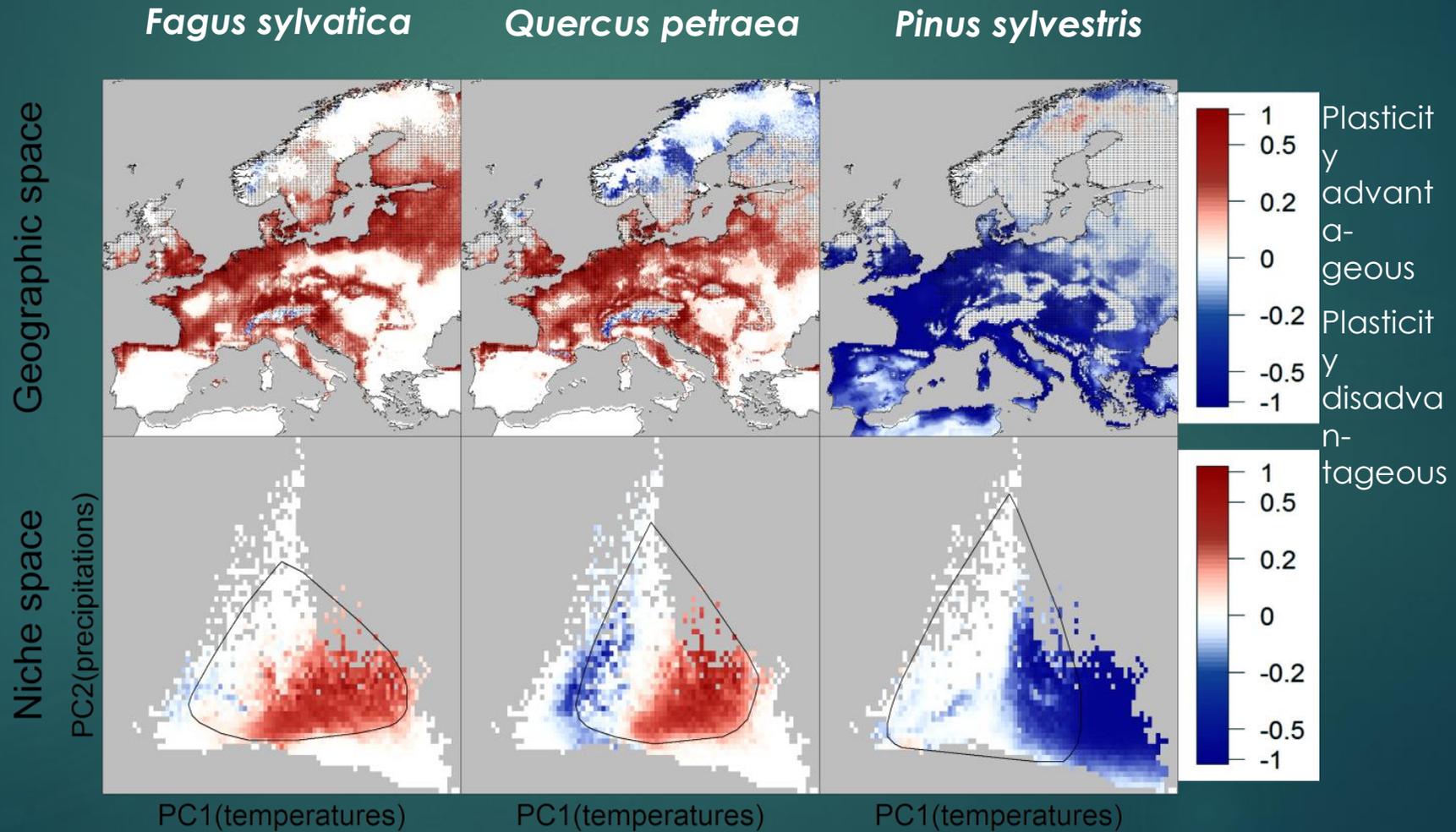
Is plasticity adaptive in future conditions?

➤ and not only because of the trend effect

	Range change		
Year-to-year (1-1/0)			
Spatial (1-2/1)			
Trend (1-3/2)	- 37.7%	- 23.0%	- 1.4%
All effects (1-3/0)			

Is plasticity adaptive in future conditions?

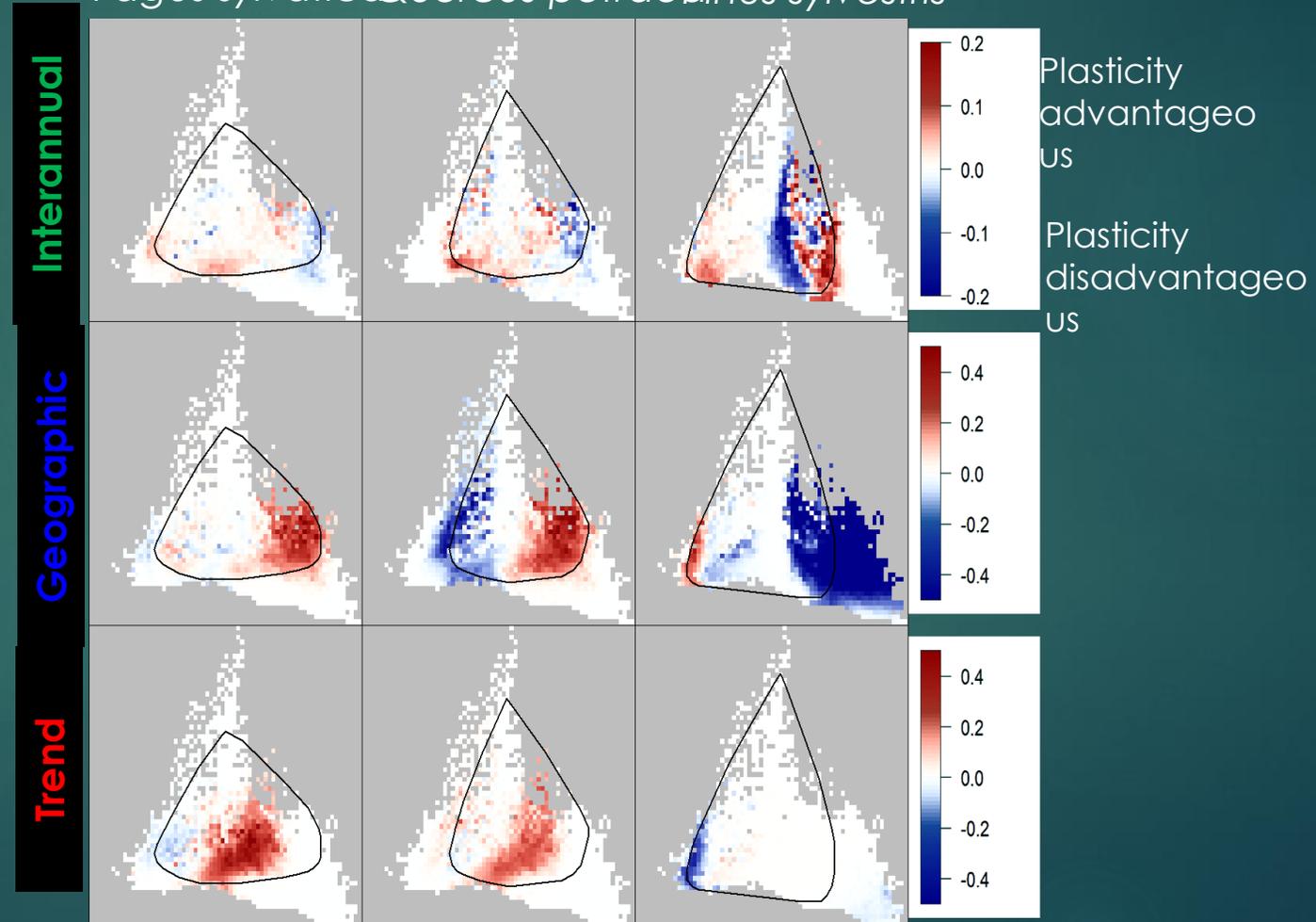
Model 0 (plastic) – Model 3 (fixed to rangewide 1981-2000 average)



Is plasticity adaptive in future

conditions?
Contribution of plasticity to fitness in 2100

Fagus sylvatica *Quercus petraea* *Pinus sylvestris*



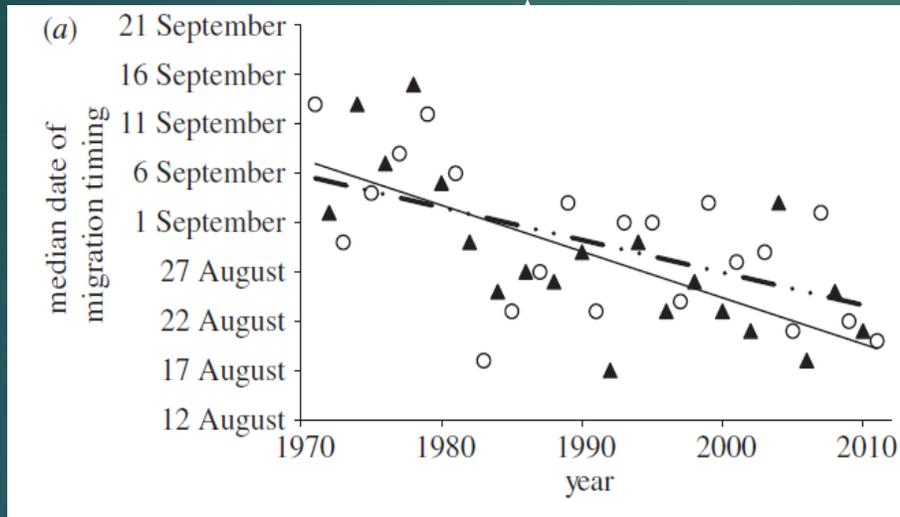
Take home messages

- Phenotypic plasticity may also translate developmental constraints
- Interannual variability in budburst/senescence dates weakly impacts fitness, but confers a fitness load on the inner margin and fitness gain on the outer margins of the distribution
 - + long-distance gene flow (Kremer *et al.* 2012)
 - > plasticity selected at the scale of the range?
- ... except at range/niche margins
- Phenotypic plasticity will help species increase their range size in future climatic conditions

3. Evolution

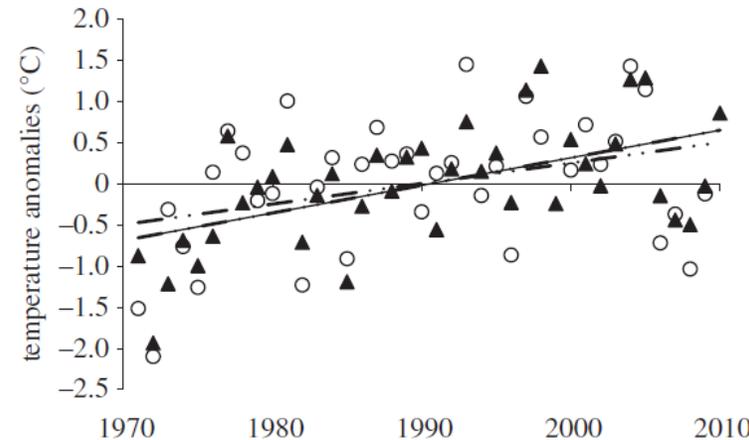
Phenological traits are adaptive traits

- Micro-evolution of phenological traits is underway in many organisms due to climate change



Pink salmon in Auke creek, Alaska

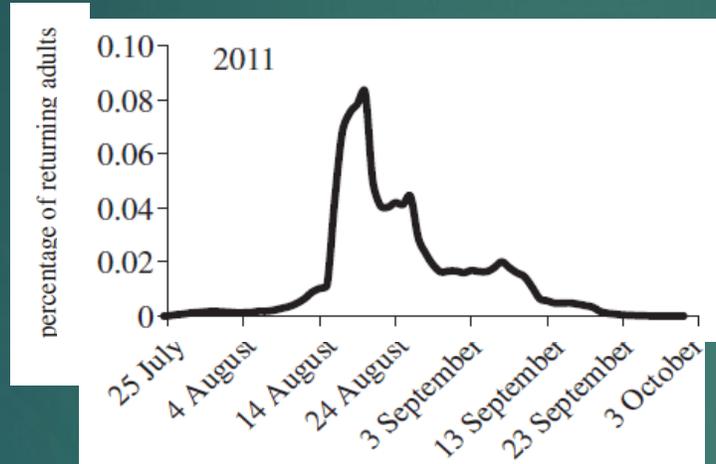
Is the trend in migration date only the result of plasticity?



3. Evolution

Phenological traits are adaptive traits

- Micro-evolution of phenological traits is underway in many organisms due to climate change



Pink salmon in Auke creek, Alaska

