IPK GATERSLEBEN

BAYERISCHE FORSTVERWALTUNG

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Variability of Response to Climatic Extremes within Key Species of Central European Ecosystems

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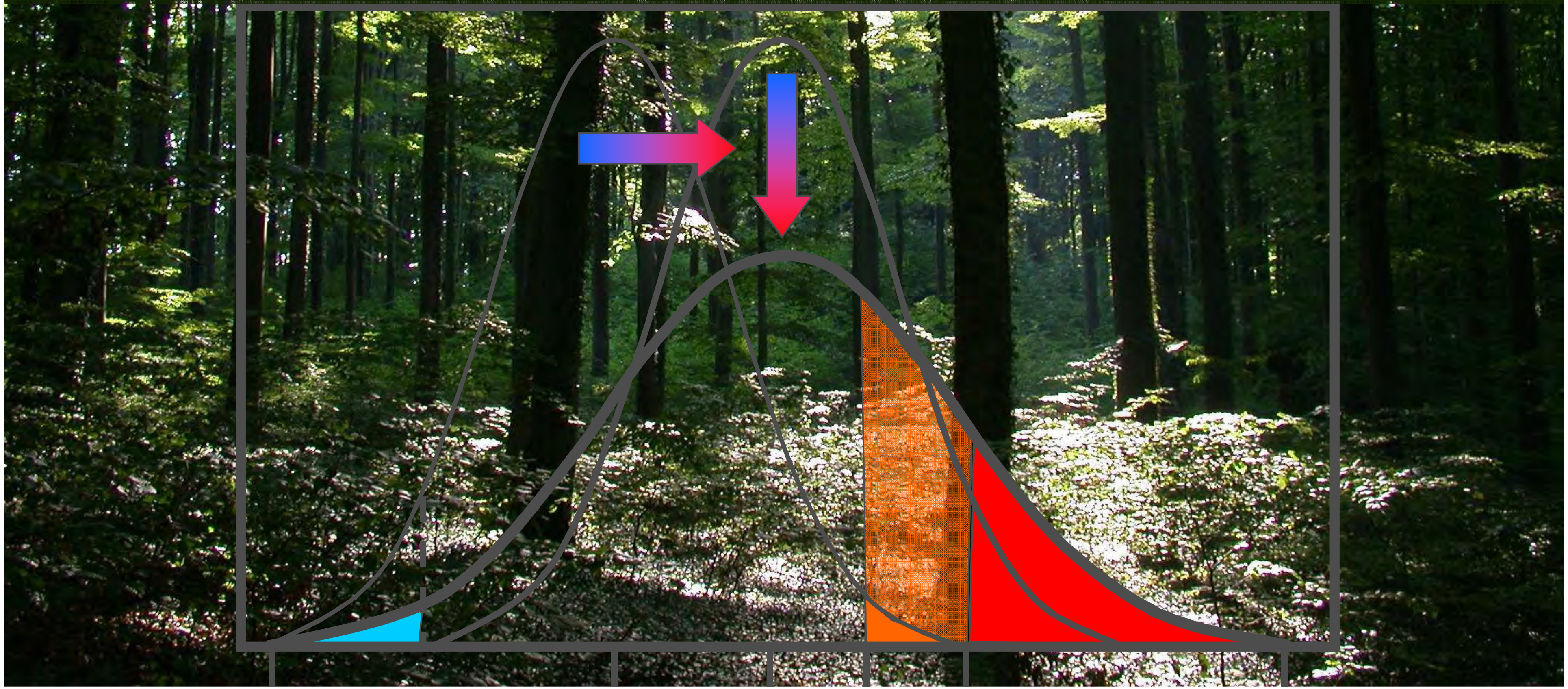

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Goals

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Preservation and adaptation of ecosystems in face of climate change and especially extreme events.

Identify adapted populations / provenances within important key species.

Assisted migration of phenotypes within species?

Establishment of designed ecosystems with mixed populations that cover a range of expected future climatic conditions?

Inspector Gregory:

Is there any point to which you would wish to draw my attention?

Sherlock Holmes:

To the curious incident of the dog in the night-time.

Inspector Gregory:

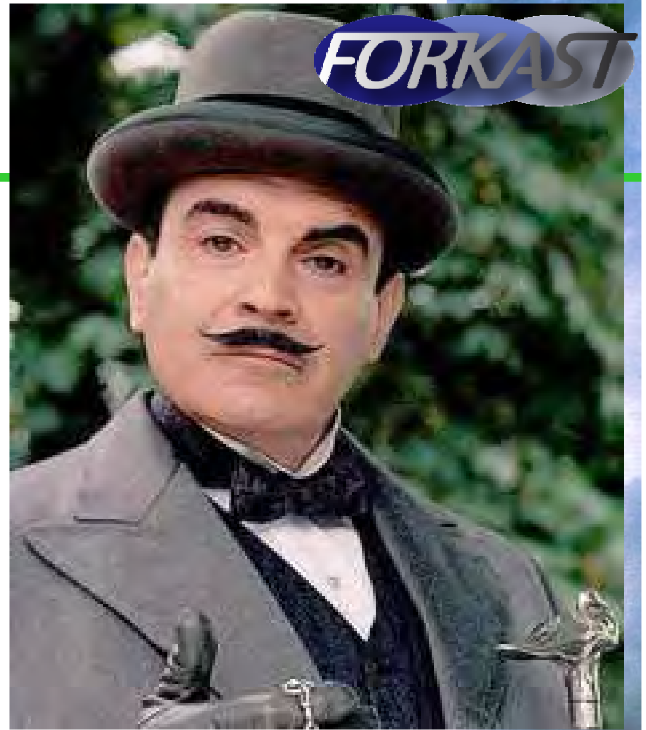
The dog did nothing in the night-time!

Sherlock Holmes:

That was the curious incident!

(in „Silver Blaze“ by A.C. Doyle)

What is the „signal“ of something that does not exist or happen?



"And I may say that though I have now arrived at what I believe to be the true solution of the case, I have no material proof of it.

I know it is so, because it must be so, because in no other way can every single fact fit into its ordered and recognized place"

- Hercule Poirot
(in "Murder in Mesopotamia"
by Agatha Christie)

Perhaps, he is right, perhaps, he is just biased!

"We need action"

Arnold Schwarzenegger
(former Gov. of California)

15th of December 2010, COP 15; Copenhagen

This is quite clear in the field of mitigation and carbon sequestration!

But, in the field of adaptation we are not really sure what to do!

Structure

1 Ecology of Climatic Extremes

2 What is Extreme ?

3 Within-Species Variance and Limits of Projection

4 Experiments on Key Species

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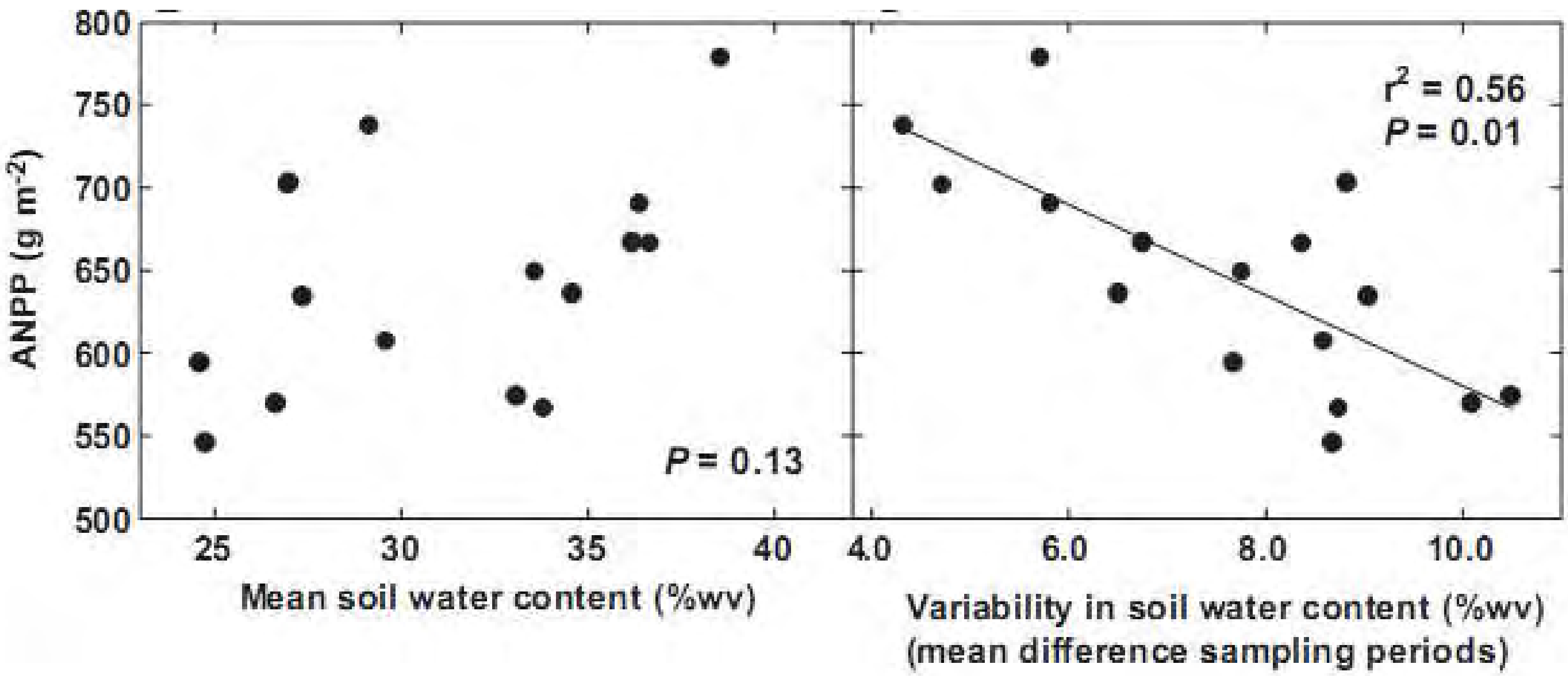
Ecology of Extremes

Die-off at *Sphagnum fallax* at spring sites in summer 2003

Ecology of Extremes

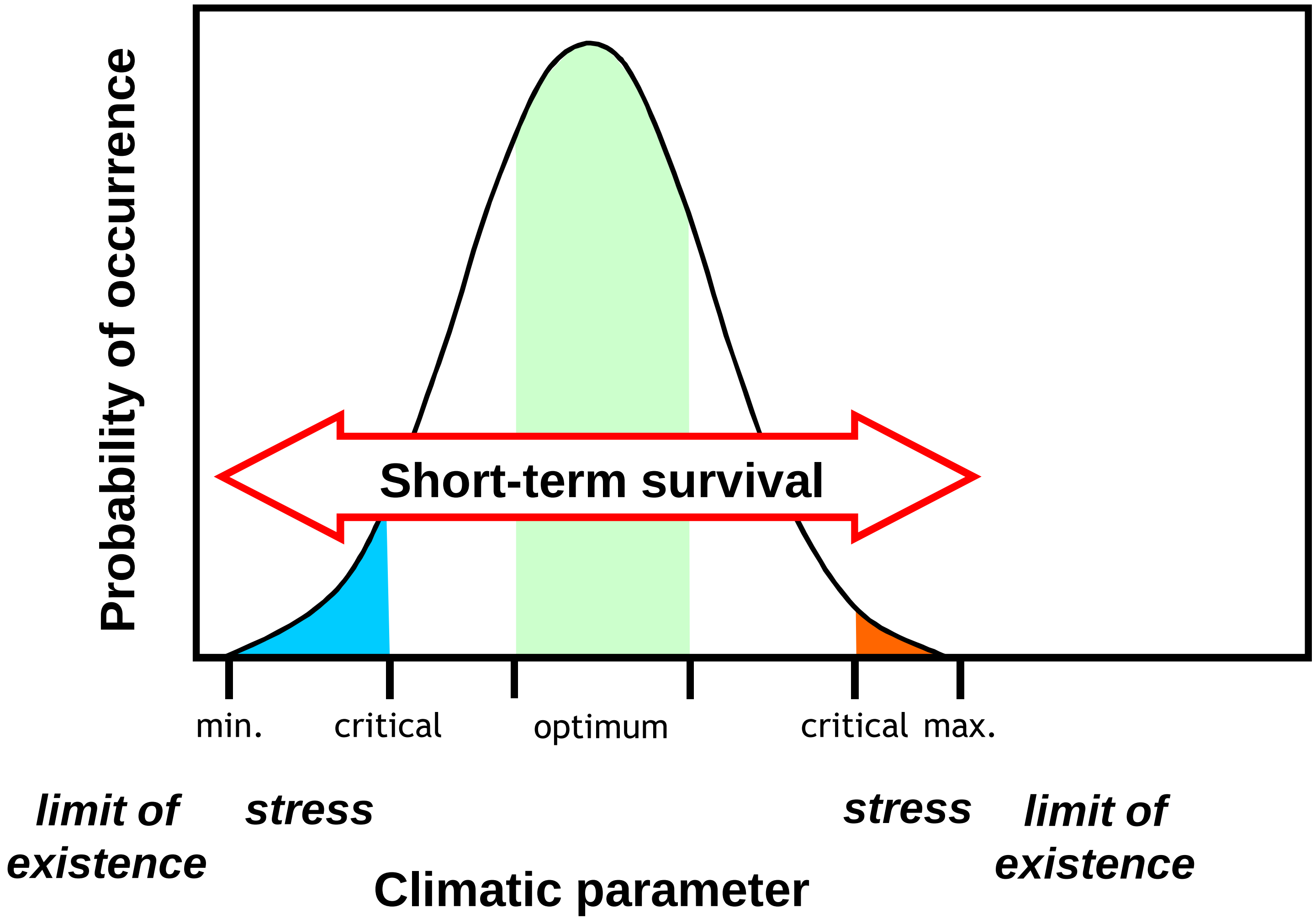
Productivity can be correlated with variability
- not necessarily with averages



Knapp et al. 2002 Science

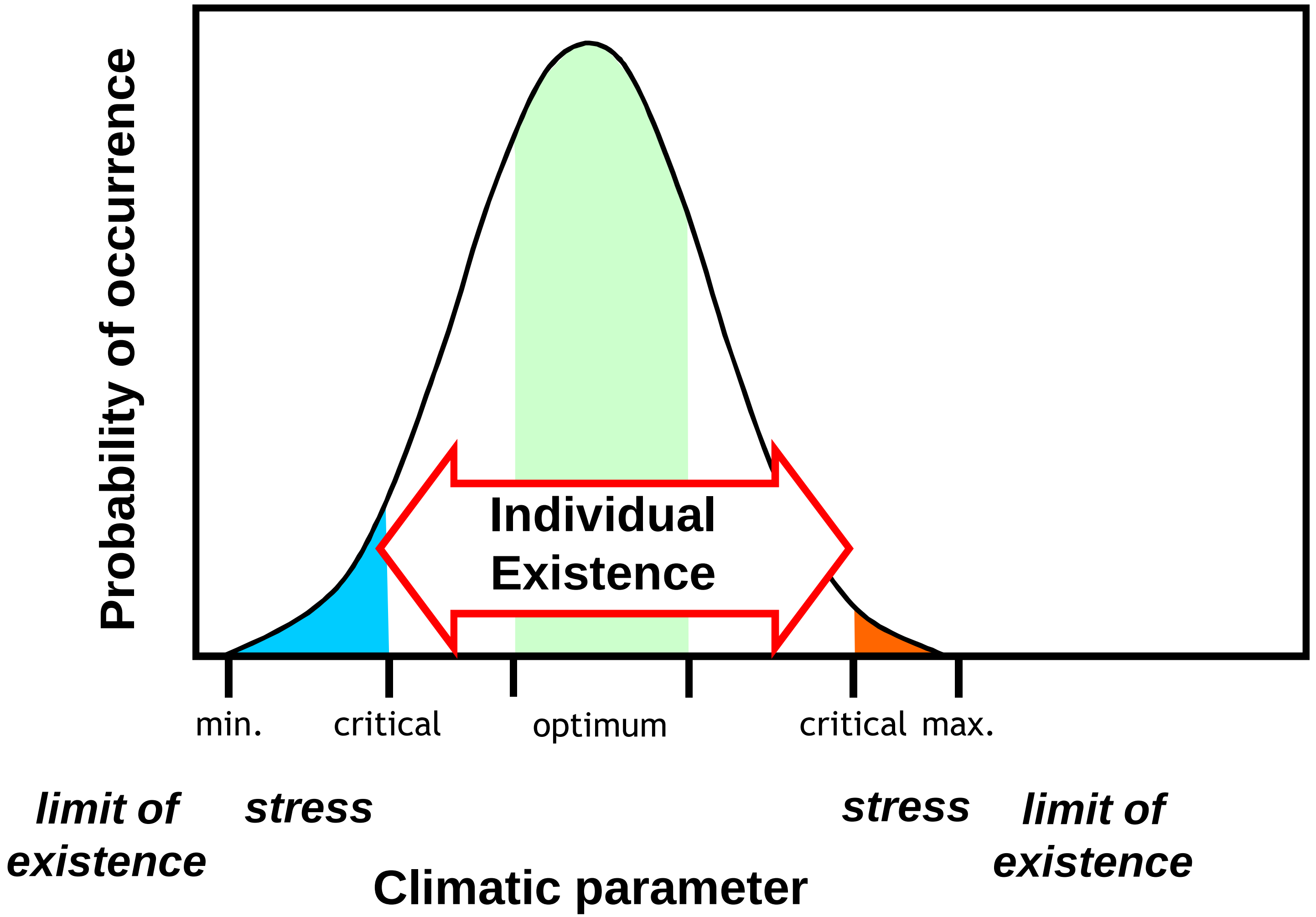
Ecology of Extremes

Climatic limits of *Species A*



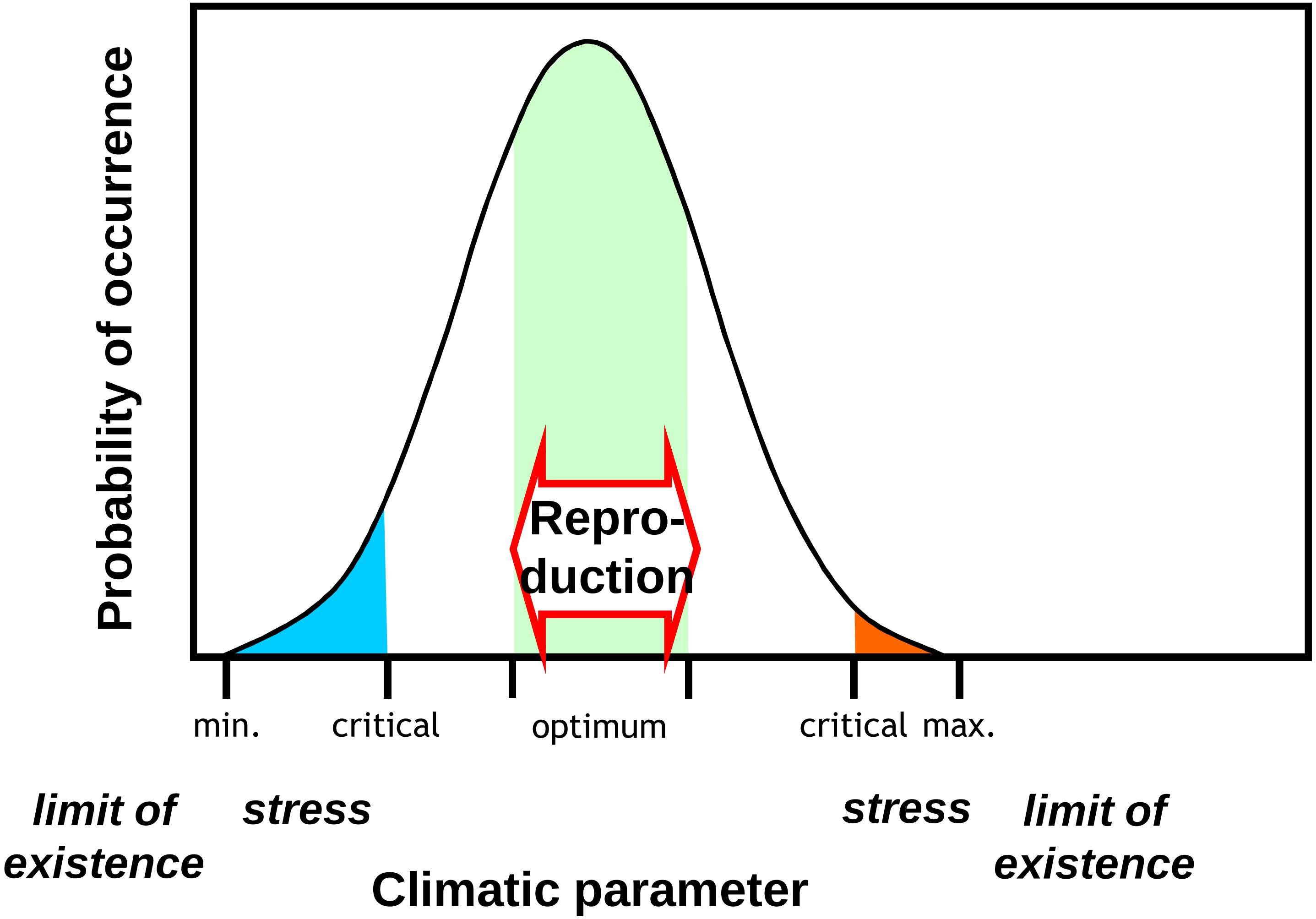
Ecology of Extremes

Climatic limits of *Species A*



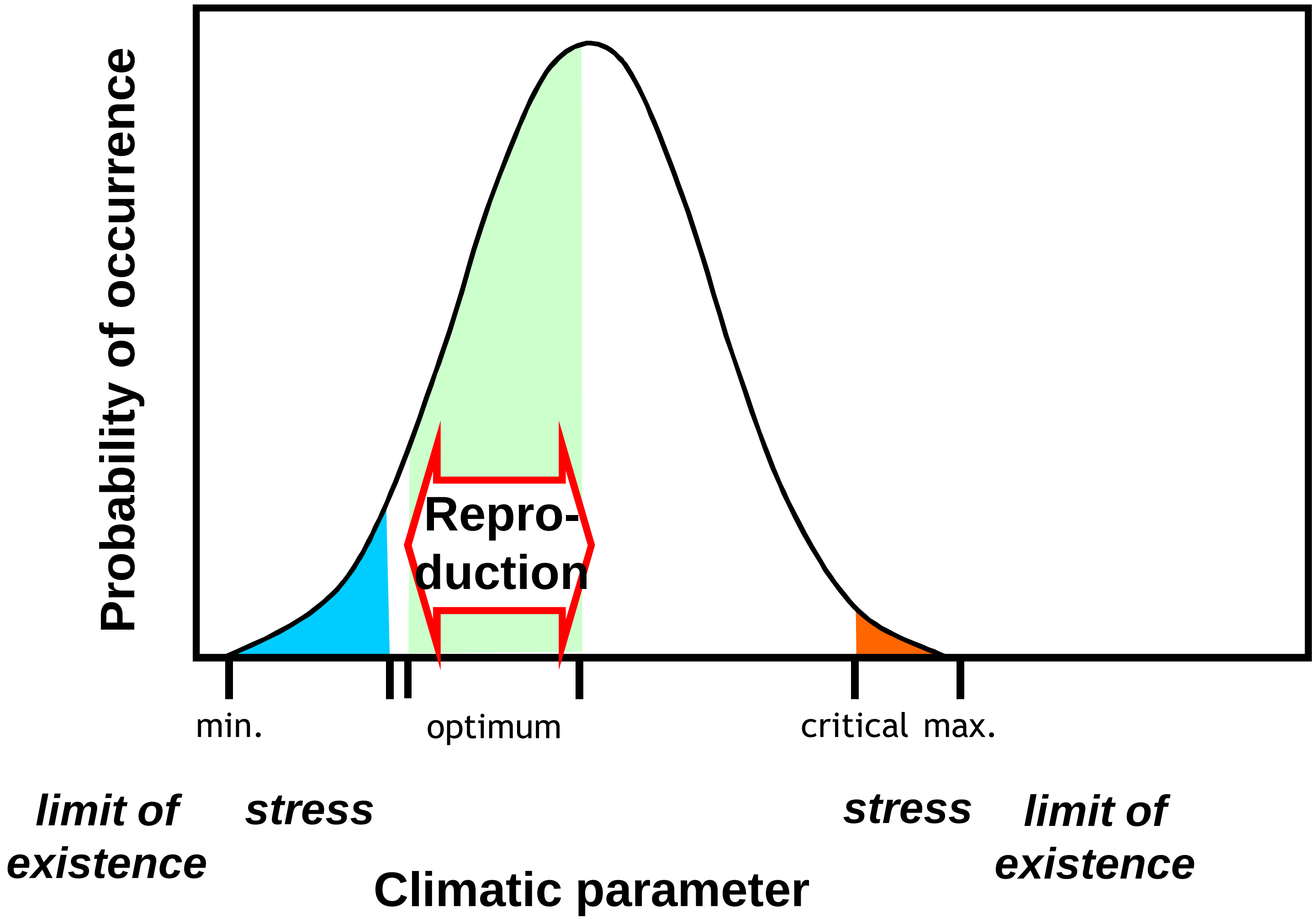
Ecology of Extremes

Climatic limits of *Species A*

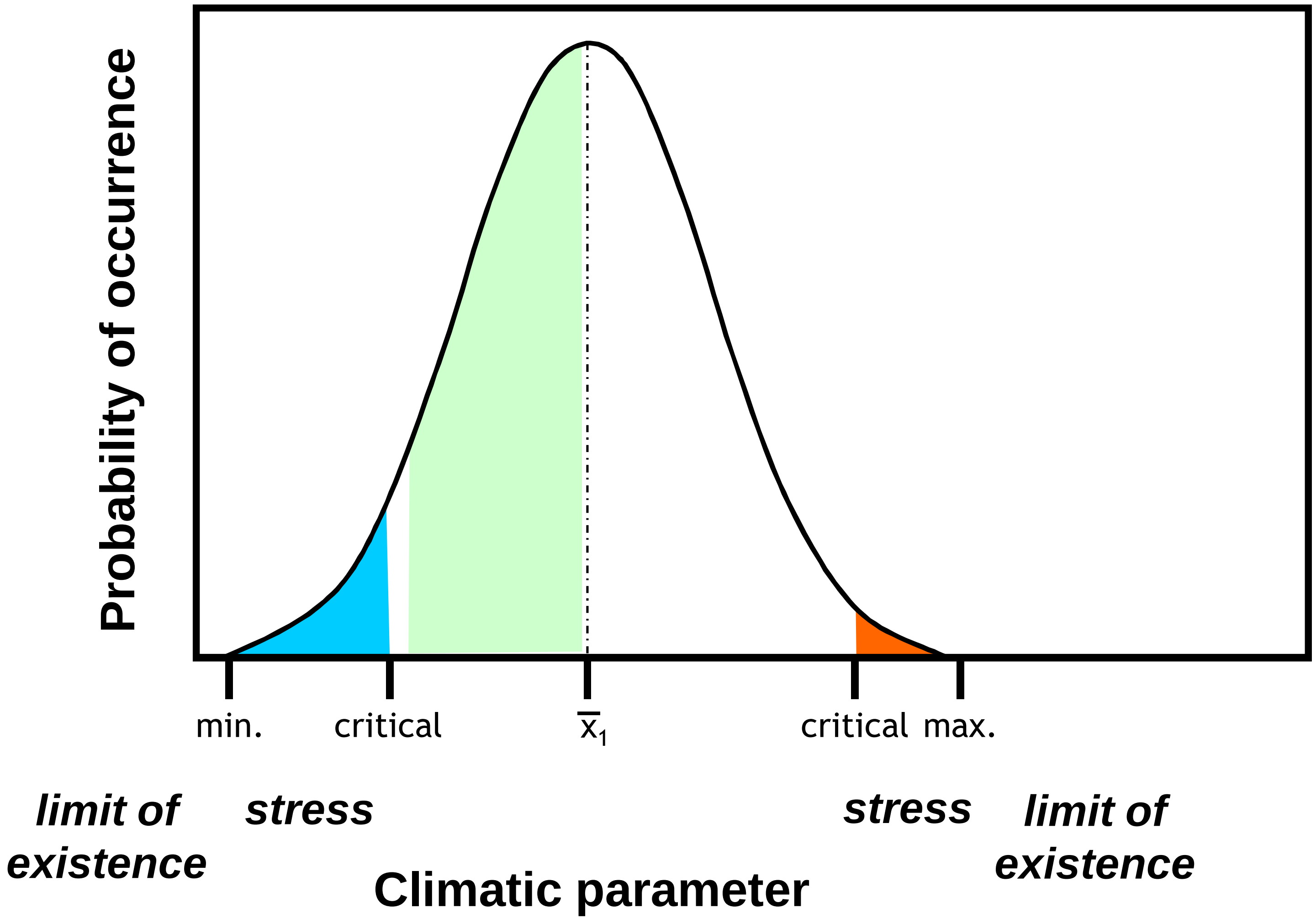


Ecology of Extremes

Climatic limits of *Species B*

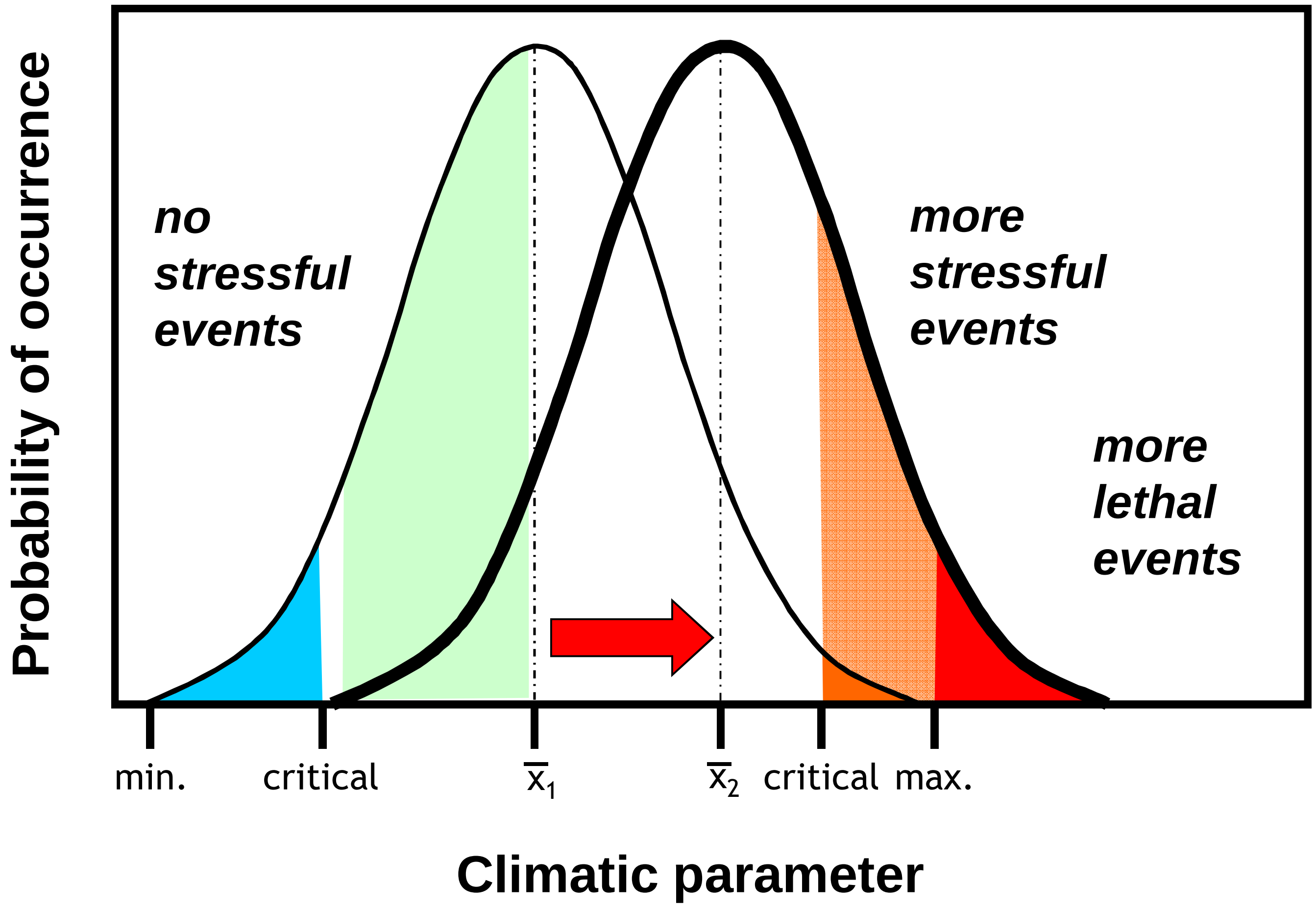


Ecology of Extremes



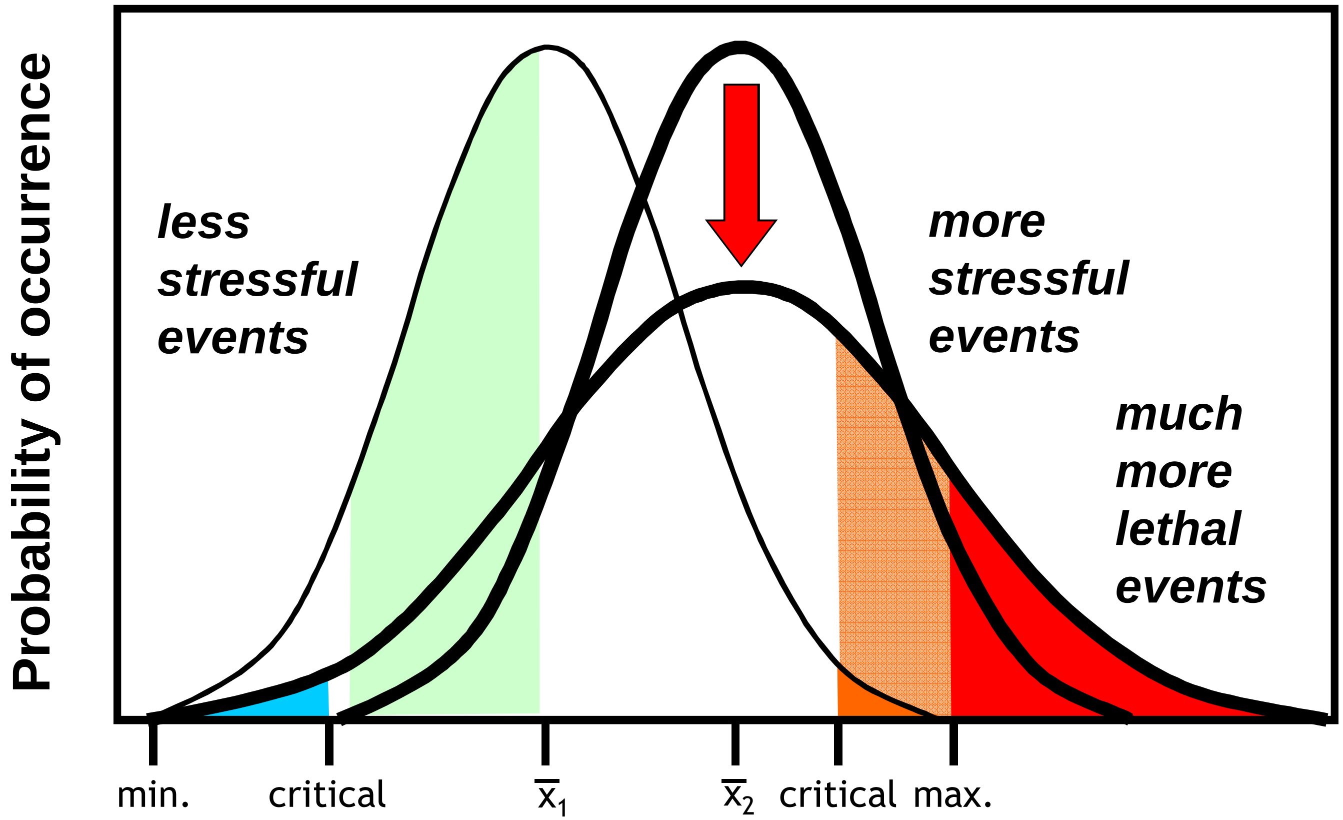
Ecology of Extremes

Symmetrical shift

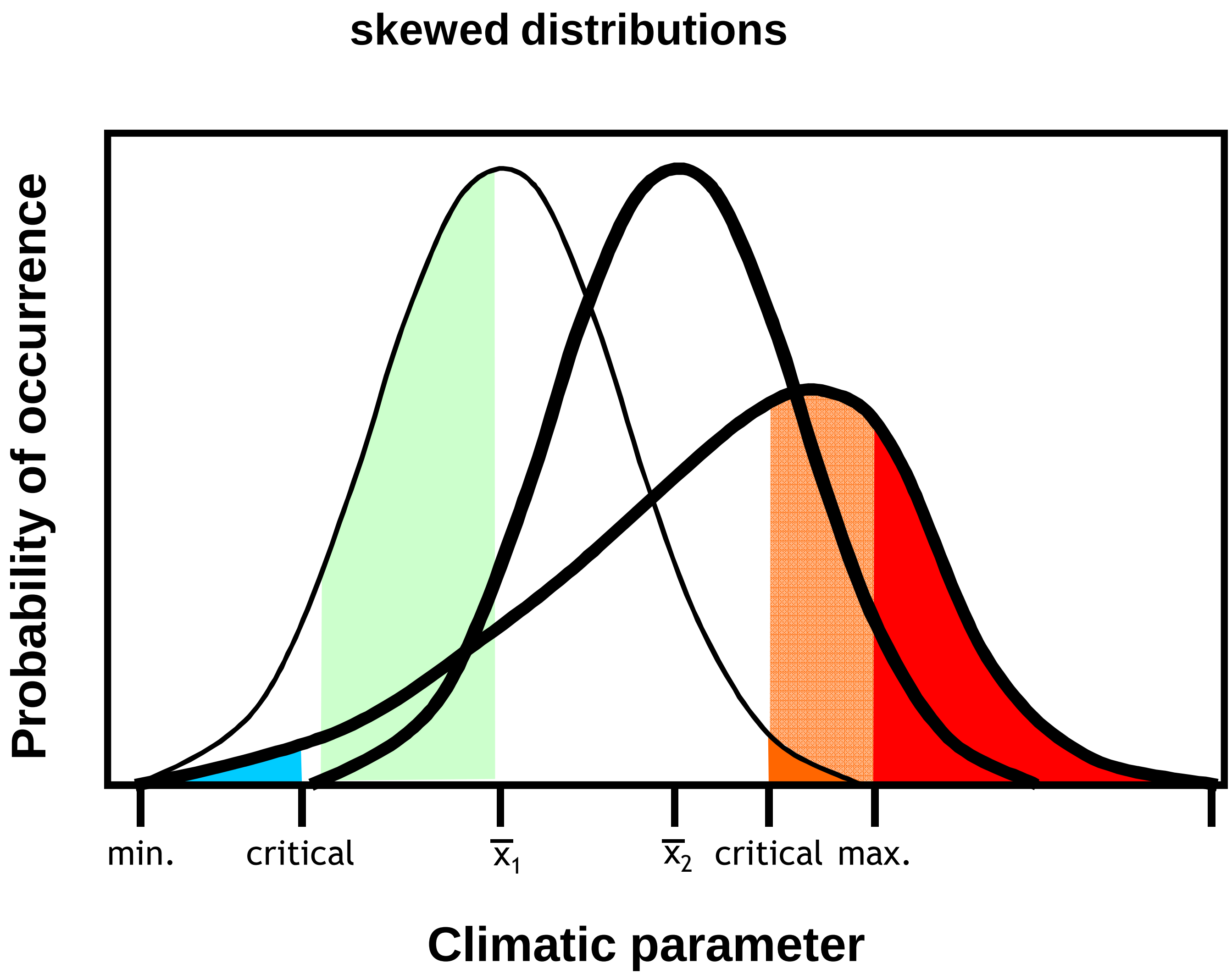


Ecology of Extremes

Shift of the shape of the distribution



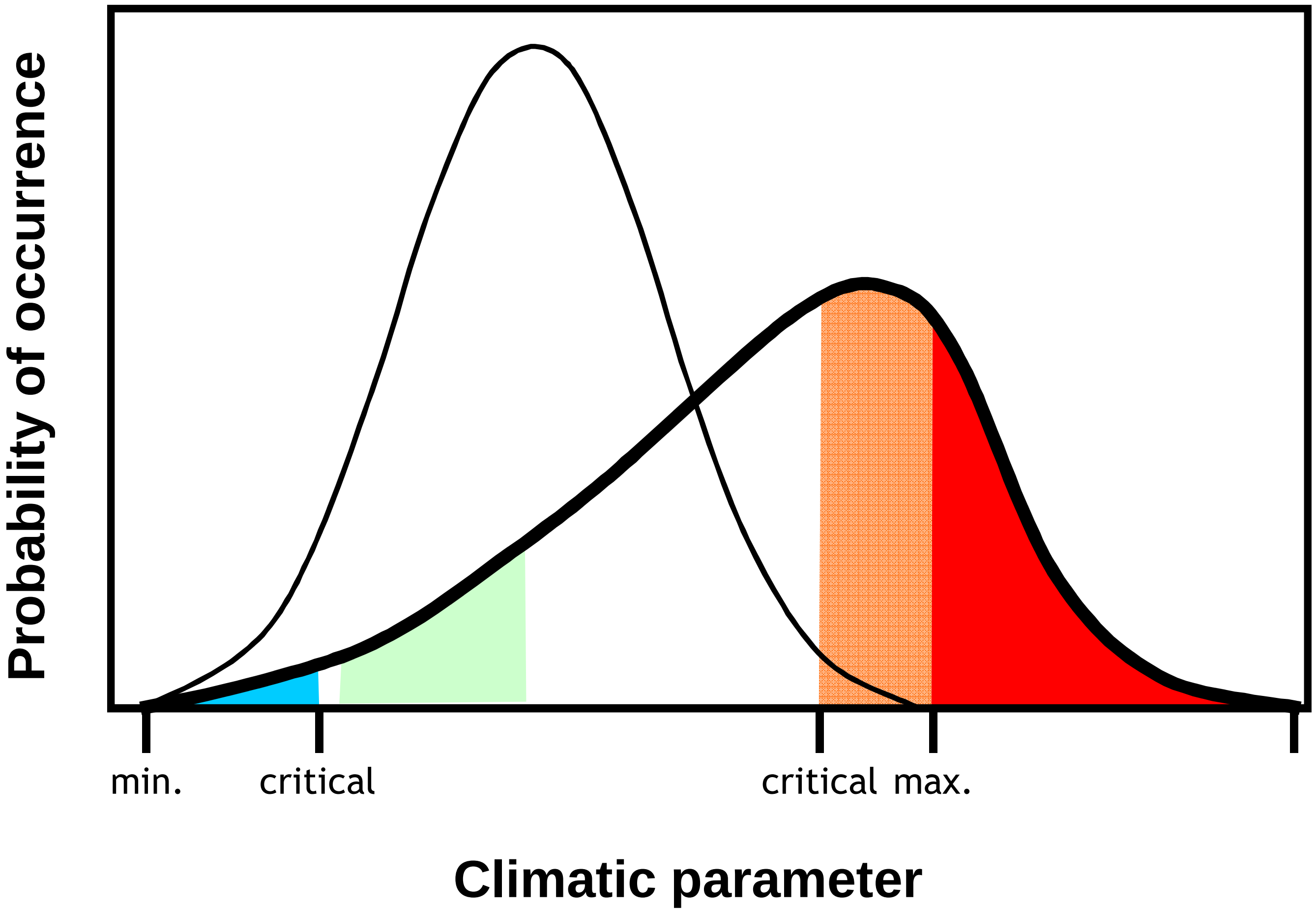
Ecology of Extremes



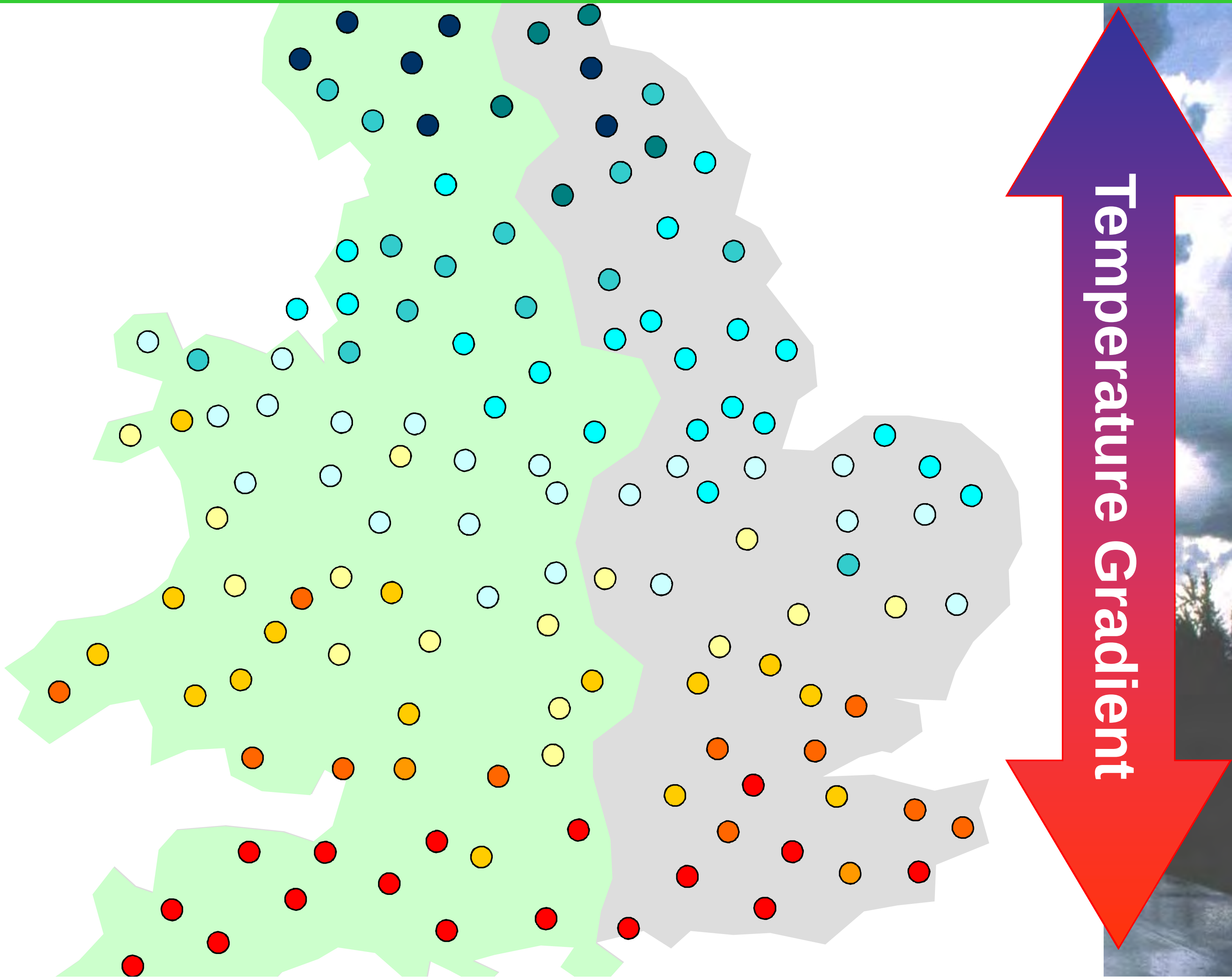
Ecology of Extremes

Almost no reproduction events of Species B

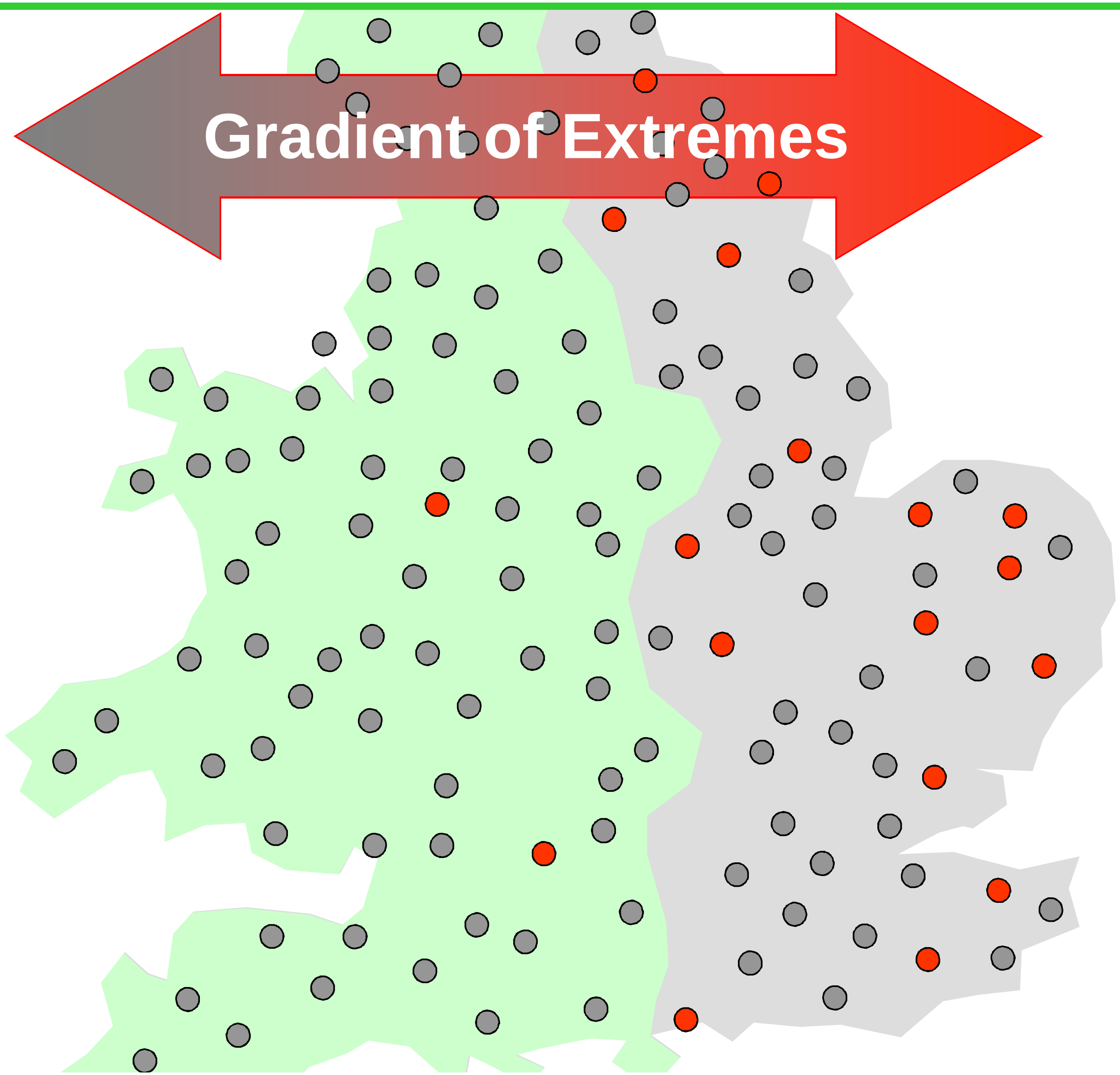
High probability of local extinction of Species B



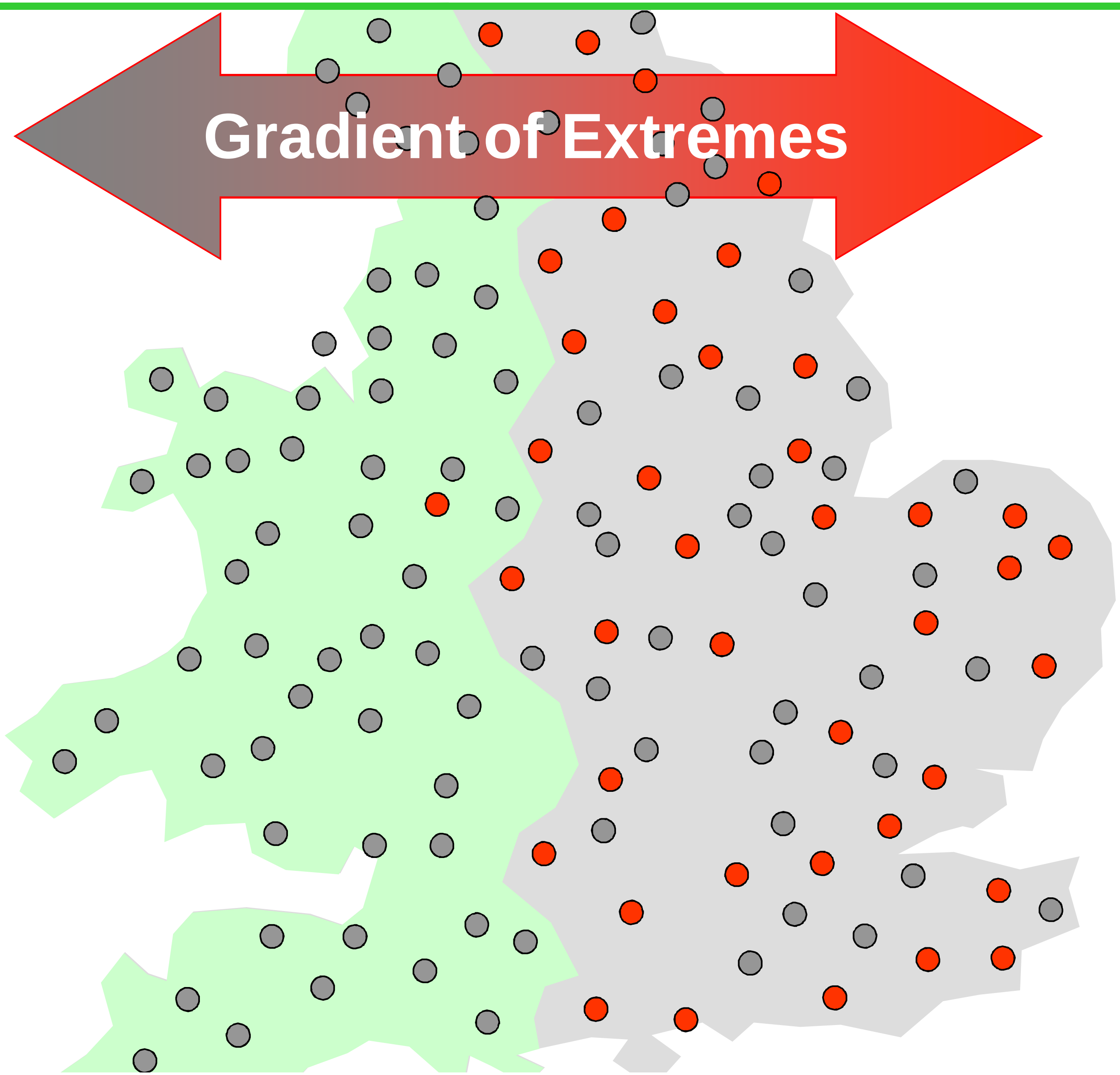
Ecology of Extremes



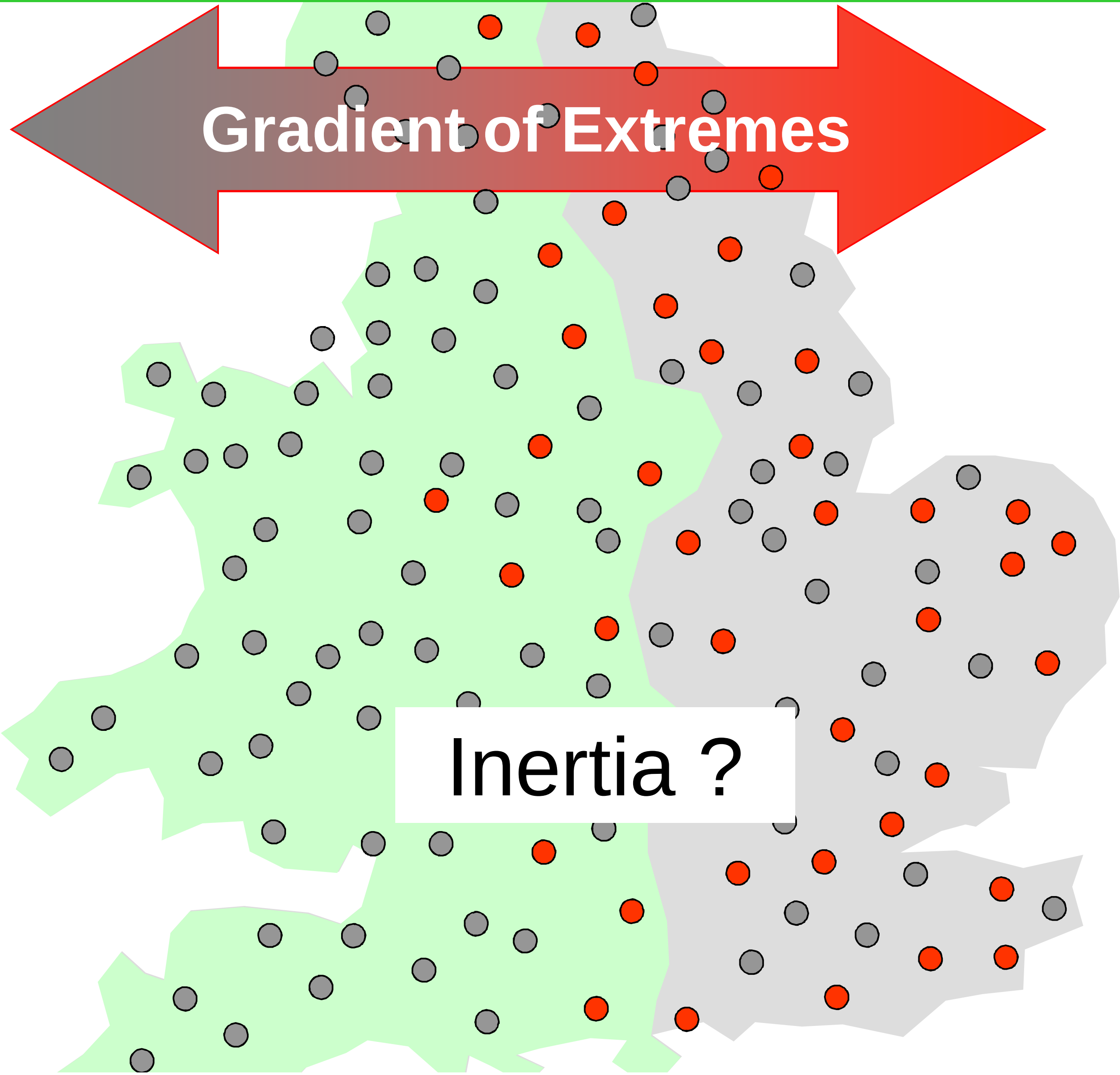
Ecology of Extremes



Ecology of Extremes



Ecology of Extremes



Ecology of Extremes

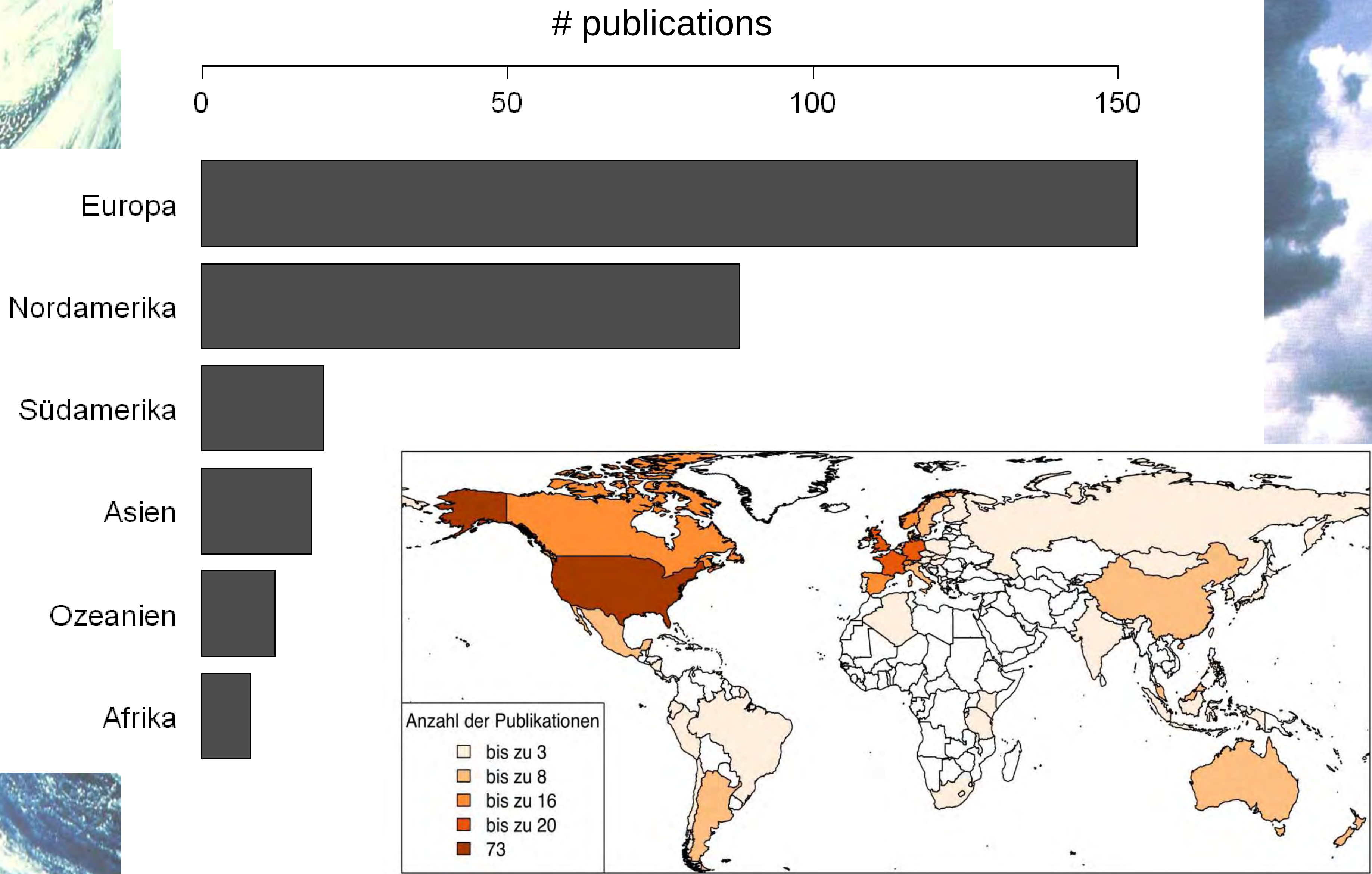
Emerging research challenges include (Jentsch & Beierkuhnlein 2008):

- the significance of extreme weather events for local establishment and extinction;
- the modulating role of event regimes and biodiversity for community dynamics;
- ecological inertia, induced tolerance and regeneration dynamics after extreme weather events;
- the effects of extreme weather events on ecosystem functioning.

Here, we add the role of intraspecific diversity of phenotypes.

Jentsch & Beierkuhnlein 2008 Research frontiers in climate change: Effects of extreme meteorological events on ecosystems. CR Geosciences 340: 621-628

Ecology of Extremes



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What is Normal ?

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What is Extreme?

Extreme summer drought and heat wave

Central Europe 2003

Effect-oriented definitions?



What is Extreme?

If the probability of occurrence is changing in time as a consequence of a temporal trend

– this has consequences for the statistical sample (e.g. time series, mean values, percentiles, probabilities).

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What is Extreme?

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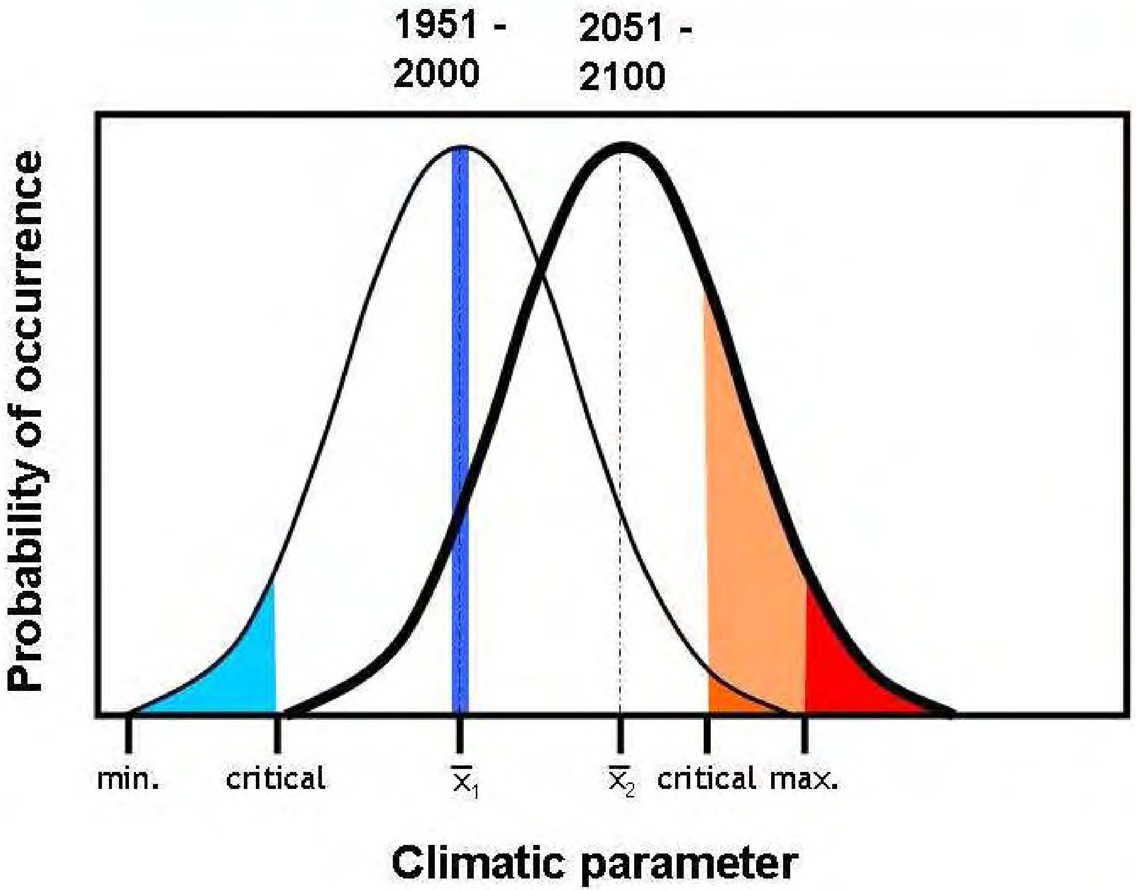
An event that used to be “normal” 100 years ago may become “extreme” in the future!

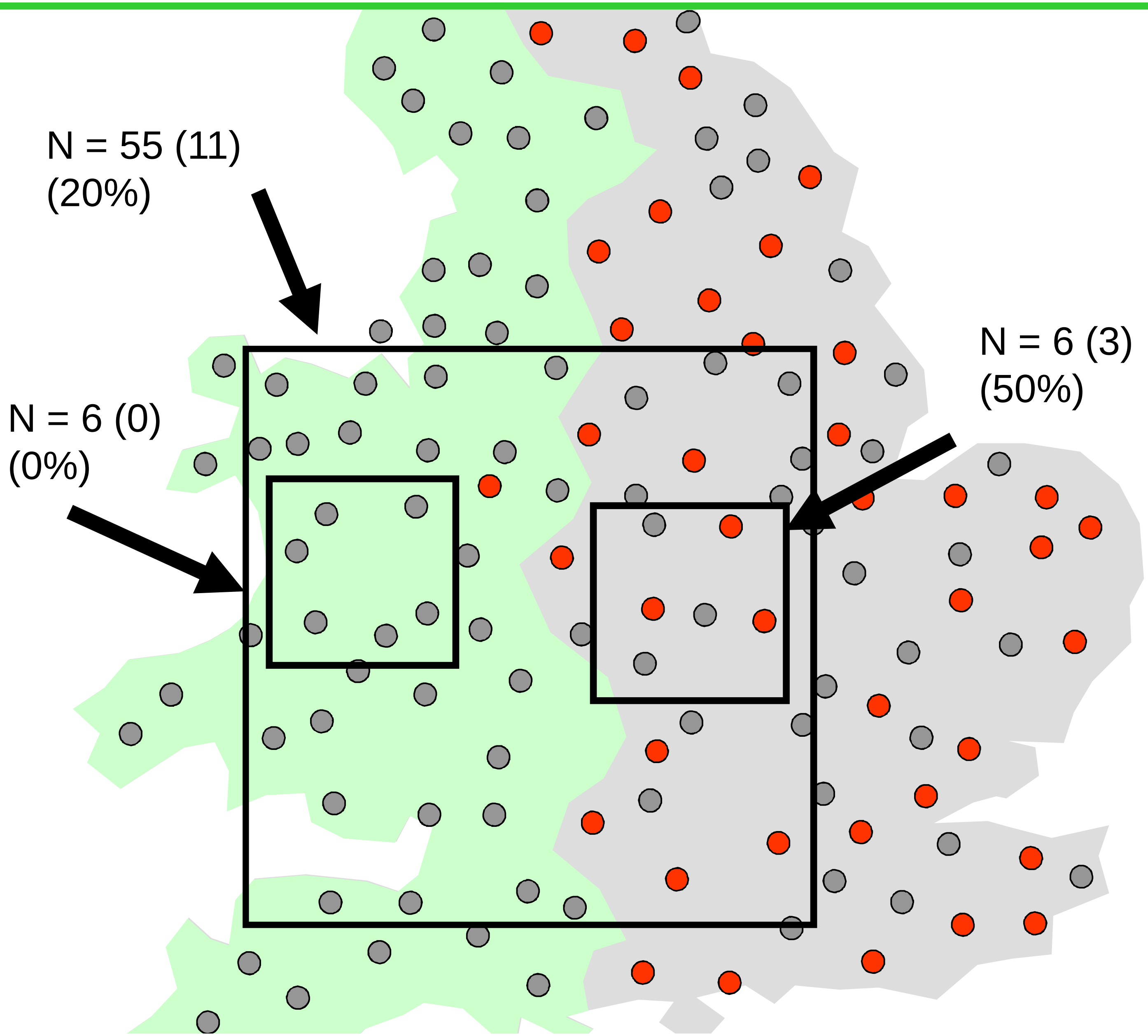


What is Extreme?

An event that is “normal” in a neighbouring region can be extreme here! – Spatial Gradients

Changing the scale of observation will modify “extremeness” of values. – Size of Area

Ecology of Extremes



What is Extreme?

If trends are occurring (in space and in time) – extremeness is always relative to the present day and to the present spatial scale that is considered.

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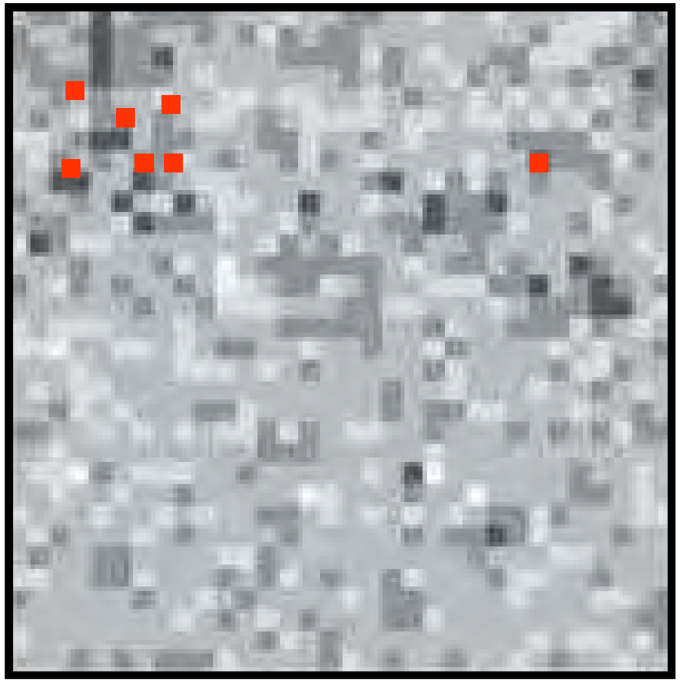
What is Extreme?

Grains size of spatial resolution is influencing the values. For organisms micro-scale events are important and these are hidden in climatic data.



What is Extreme?

A certain event at a certain region is different from the same event in another region!

What is Extreme?

A certain event at a certain time of the year has different effects 100 years ago and today - if there is an underlying trend that leads to adaptation of organisms (e.g. shift in phenology of populations by selection, epigenetic adaptatation).

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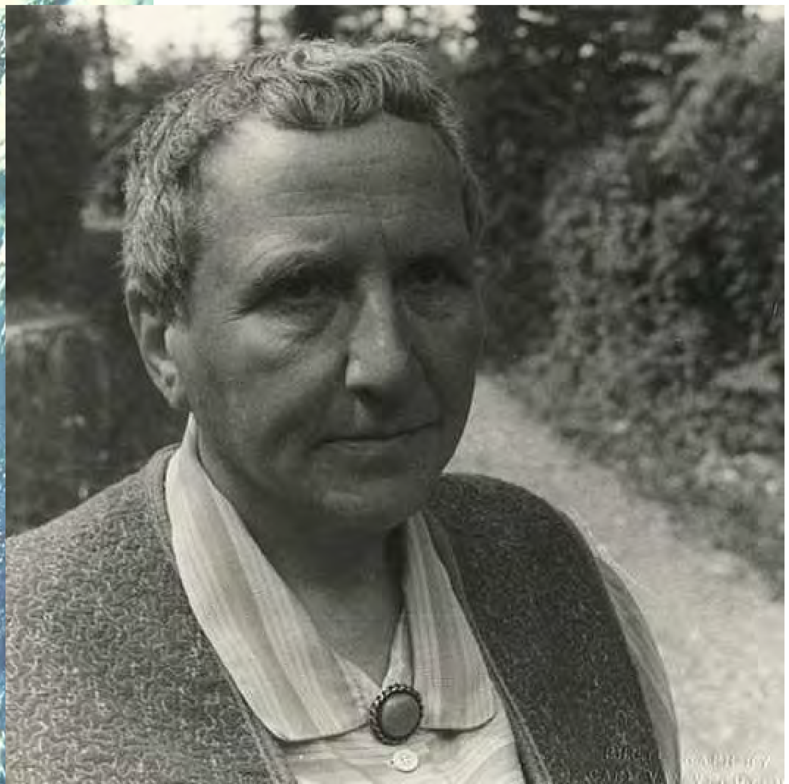
Within-Species Variance

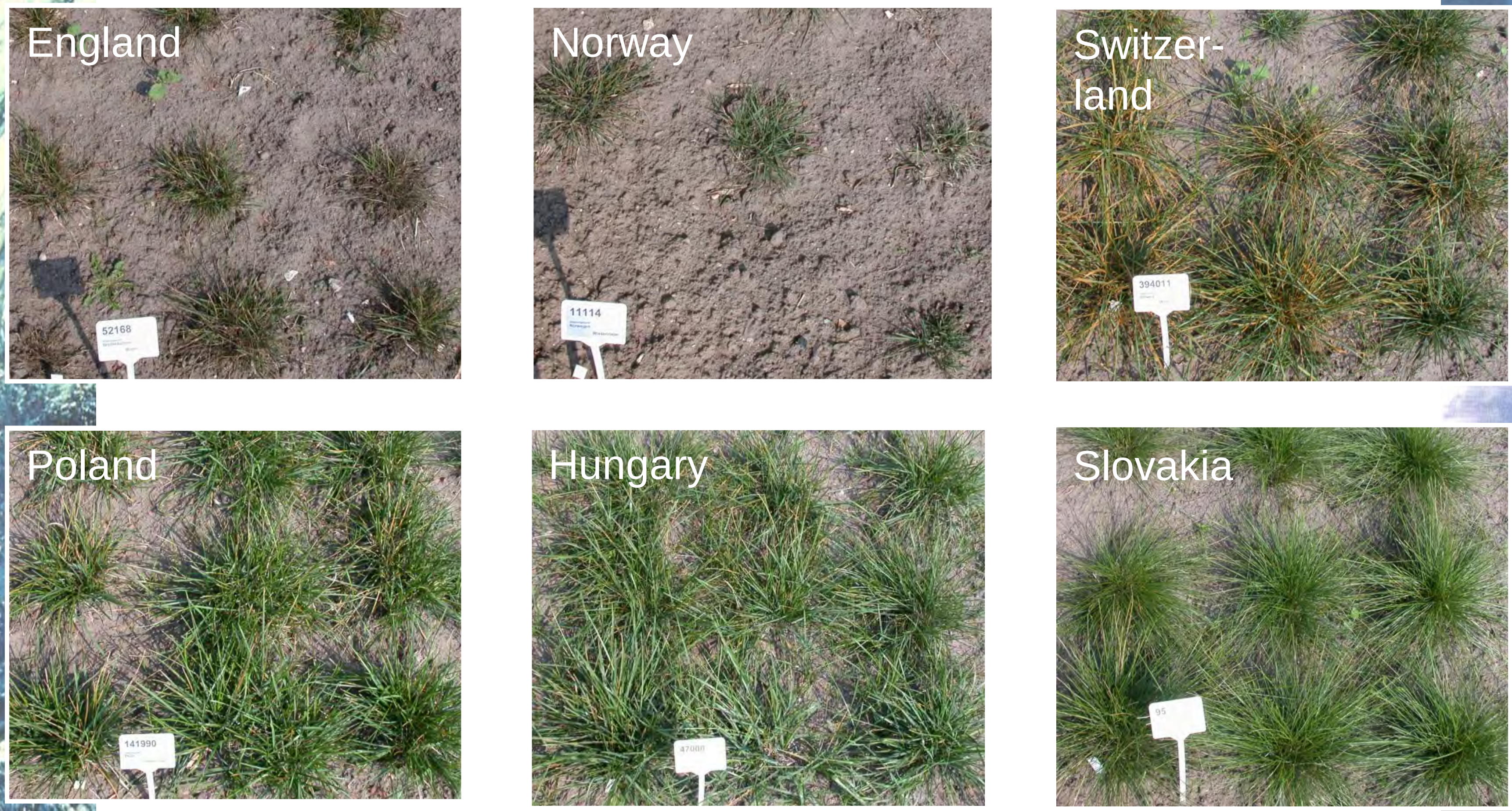
„A rose is a rose is a rose“ ???



Gertrude Stein (1874-1941)

From the poem „Sacred Emely“ in her book „Geography and Plays“ (1922)

Within-Species Variance



Poa pratensis

A grass is a grass is a grass?

Within-Species Variance

Regional pools of phenotypes can be assumed to be best **adapted to a specific (historic) environment**.

However, they represent only a **part of a species' ecological range**.

Genetic diversity is limited by dispersal history or filters.

Species specific **niches are occupied**, which creates **inertia for the immigration** from members of other populations.

Limits of Projection

climate envelope

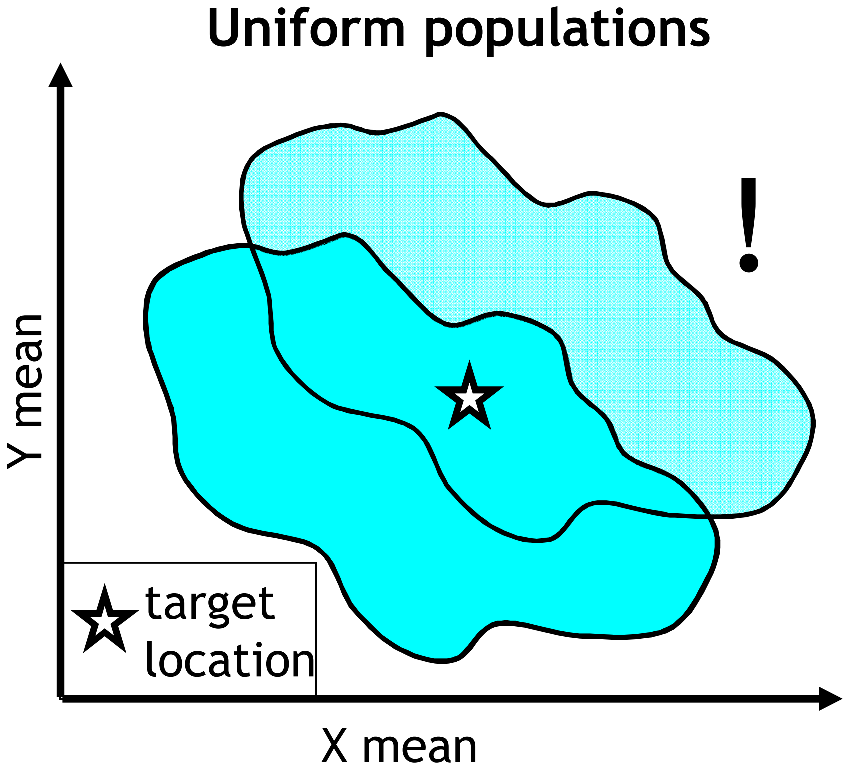
...where a species should be in the future if it is to live in the same range of climatic conditions that it does now.

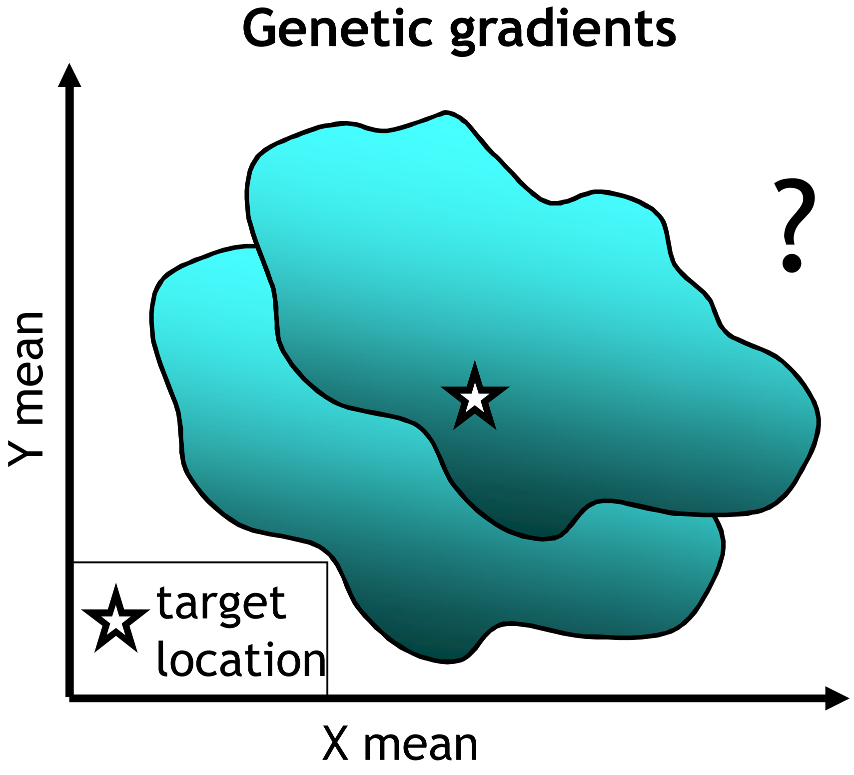
conservation and extinction issues
(*in conservation (ecology): Global Change)*

Encyclopædia Britannica. Retrieved December 14, 2010, from Encyclopædia Britannica Online: http://www.britannica.com/EBchecked/topic/1377485/climate-envelope

Limits of Projection

Climatic Envelopes based on the recent climatic range of the species may imply that key species will persist at a target location under the projected climate of the future.





Limits of Projection

Climatic Envelopes based on the recent climatic range of the species may imply that key species will persist at a target location under the projected climate of the future.

- However, **regional differences** and **genetic gradients** of genotypes and populations within species are likely to occur.
- Approaches based on climatic envelopes do not consider **extreme climatic conditions**.

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Experiments on Key Species

European provenances of *Arrhenatherum elatius*
in the EVENT III pot experiment

EVENT - Experiments

EVENT - Experiments

EVENT 3

Biodiversity

	EVENT I	EVENT II	EVENT III	EVENT IV	EVENT V
Begin	2005	2008	2008	2010	1996 / 2009
# Replicates	5	5	21	5	2
# Plots / Pots	150	225	2352	140	64
Communities	grassland, shrubland	grassland	-	grassland, shrubland	grassland
Functional Types	grasses, herbs, legumes, shrubs	grasses, herbs, legumes	grasses, trees	grasses, shrubs	grasses, herbs, legumes
species diversity (# species / plot)	artificial 1, 2, 4	natural 9 - 32	none	artificial 1,2,4	Init. 1 – 16, now 16 - 26
Funct. diversity	1, 2, 3	none	none	1, 2, 3	1, 2, 3
Total # species	10	55	4 + 3	4	54

Jentsch, A., Beierkuhnlein C (2010) Simulating the future responses of ecosystems, key species and European provenances to expected climatic trends and events. Nova Acta Leopoldina NF 112 (384): 89-98

EVENT - Experiments

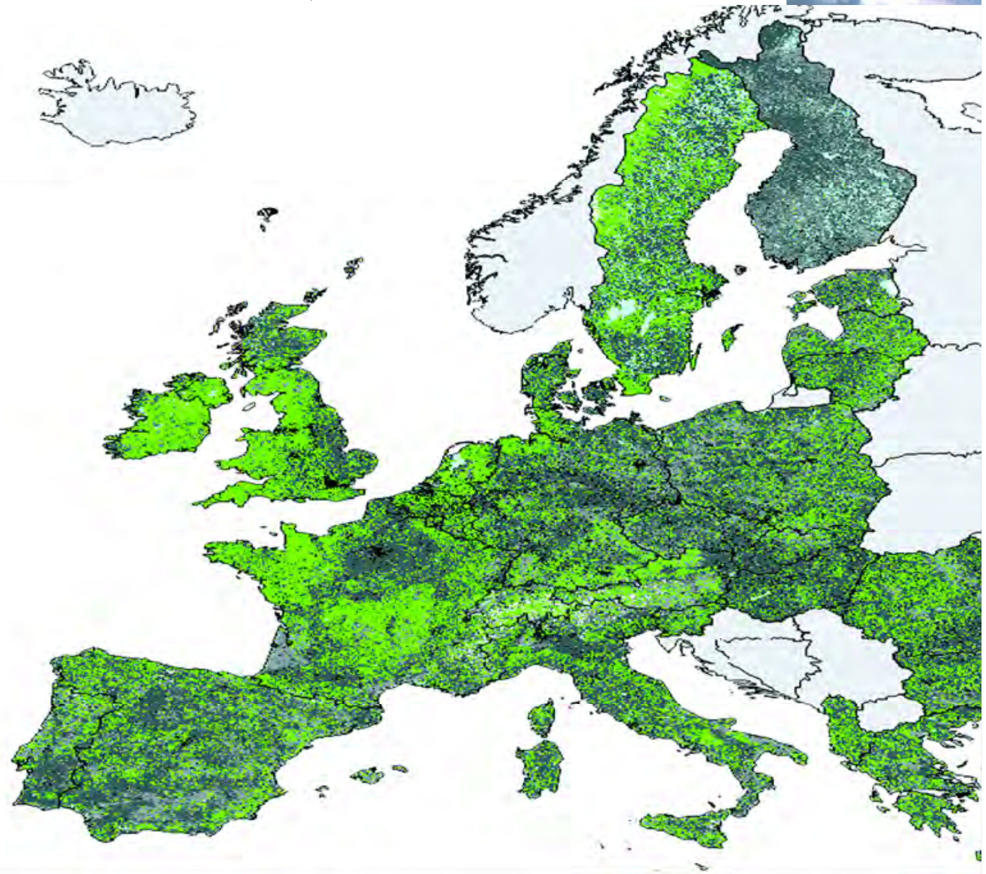
		EVENT I	EVENT II	EVENT III	EVENT IV	EVENT V
Extremes	Summer precip.	X	X	X		
	Summer drought	X	X	X		
	Frost-thaw-cycles	X			X	
Trends	Summer warming		X	X		
	Winter warming	X	X			
	+ Winter-rain		X			X
Controls	Ambient control	X	X		X	X
	Artefact control	X		X		
	Average control	X	X			
Combin.	Warming / drought		X	X		
	Warming / heavy rain		X	X		
	Warming / land use		X			

Jentsch, A., Beierkuhnlein C (2010) Simulating the future responses of ecosystems, key species and European provenances to expected climatic trends and events. Nova Acta Leopoldina NF 112 (384): 89-98

Experiments on Key Species

European agriculture in temperate and humid regions depends strongly on hay meadows. They occupy a large portion of the agricultural landscape (35 Mio ha within the EU).

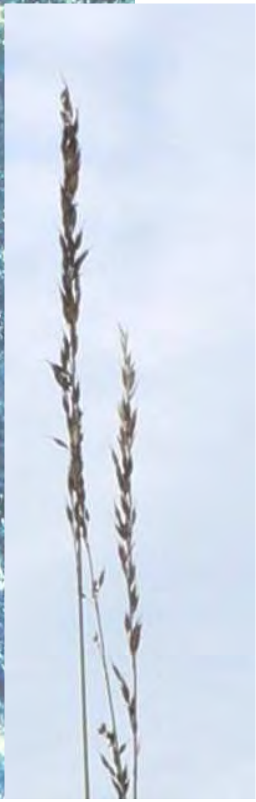
These grasslands are dominated by only few key species.



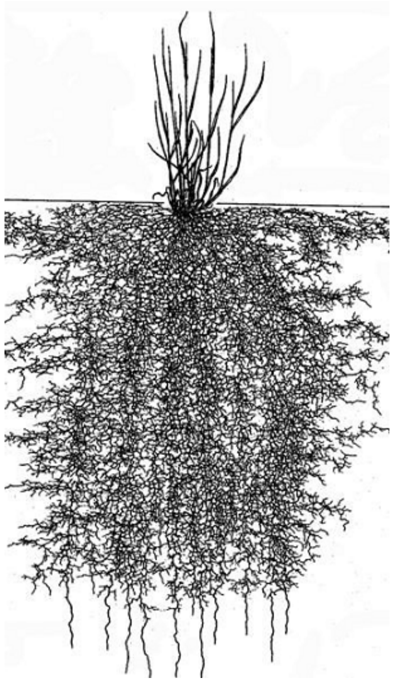
Area under permanent grassland

Experiments on Key Species

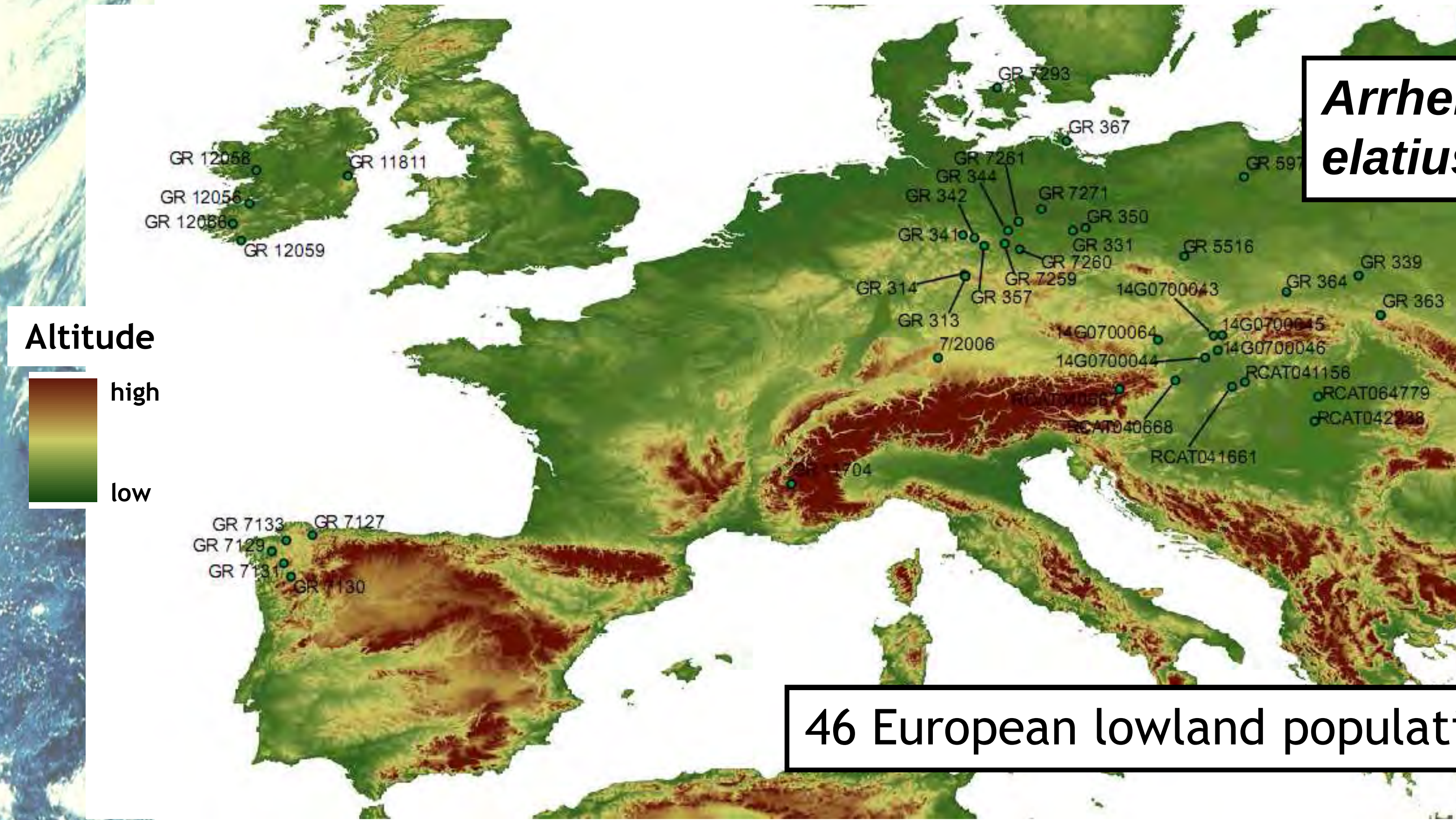
- Tallgrass that contributes substantially to biomass
- High abundance in permanent temperate grasslands
- Widespread and common species



Arrhenatherum elatius



Experiments on Key Species



Arrhenatherum elatius

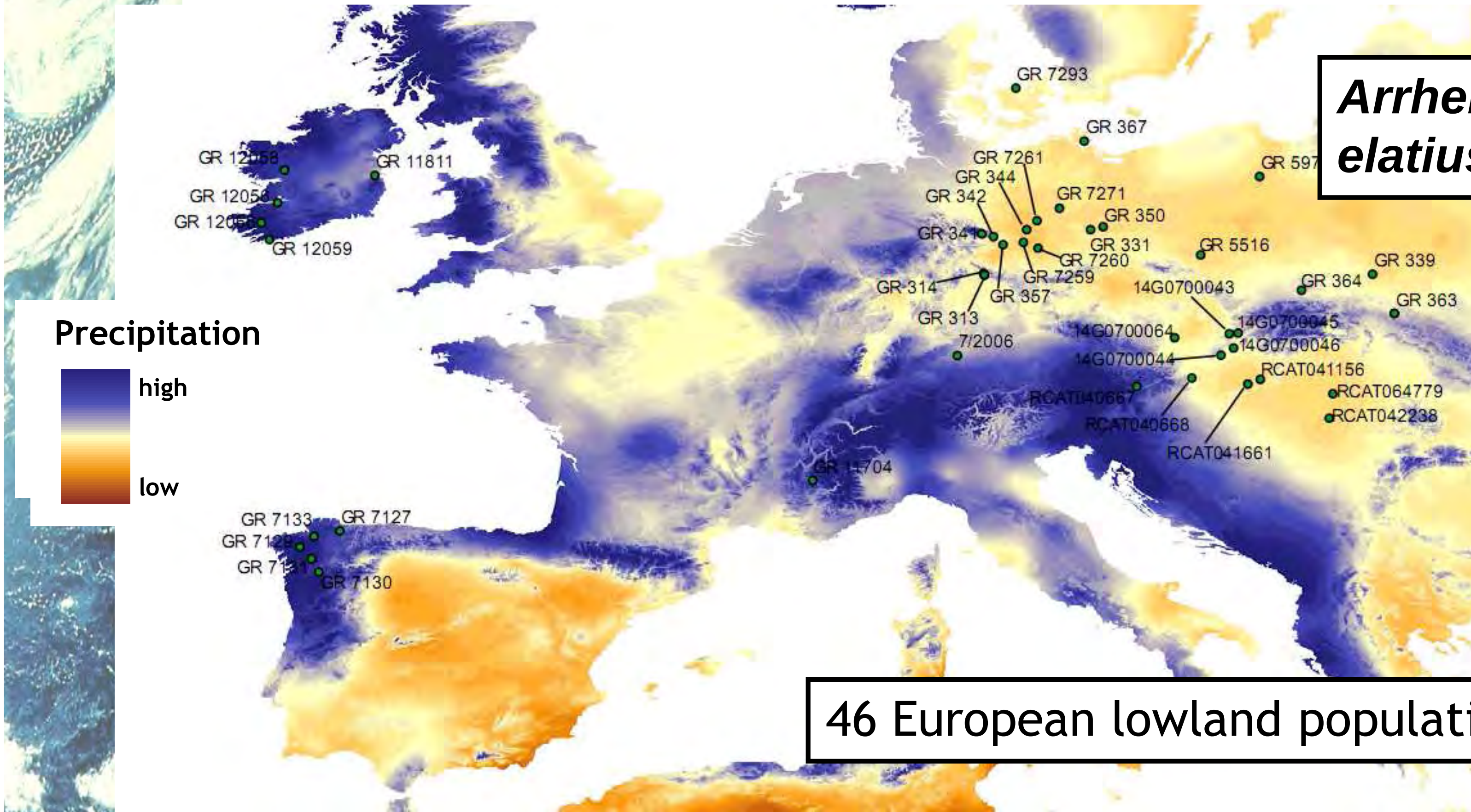
46 European lowland populations

Depending on accessibility in national seed banks.

Michalski, SG; Durka, W; Jentsch, A; Kreyling, J; Pompe, S; Willner, E; Beierkuhnlein, C (2010) : Evidence for genetic differentiation and divergent selection in an autotetraploid forage grass (*Arrhenatherum elatius*). **Theoretical and Applied Genetics 120**, 1151-1162

Experiments on Key Species

Arrhenatherum elatius



46 European lowland populations

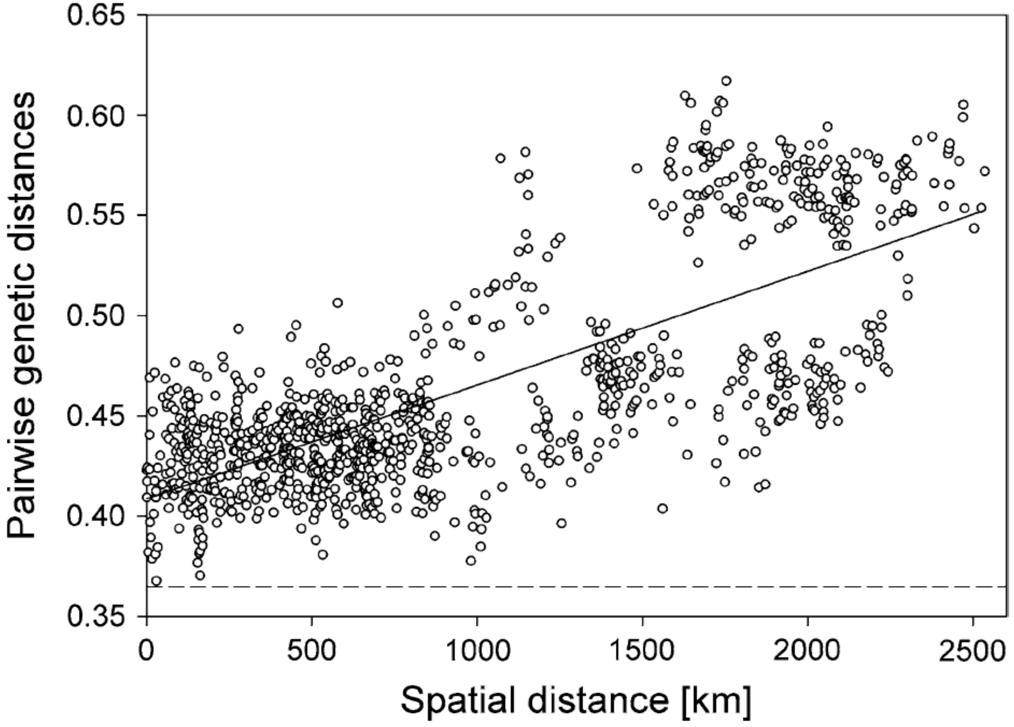
Gradient in mean precipitation (1950-2000): 482 mm (Elbe) to 1388 mm (Santiago de Compostela) – with 710 mm at the experimental site Bayreuth

Michalski, SG; Durka, W; Jentsch, A; Kreyling, J; Pompe, S; Willner, E; Beierkuhnlein, C (2010) : Evidence for genetic differentiation and divergent selection in an autotetraploid forage grass (*Arrhenatherum elatius*). **Theoretical and Applied Genetics 120**, 1151-1162

Experiments on Key Species

Although, being subject to anthropogenic land use, European key grass species in permanent grasslands perform spatio-genetic patterns.

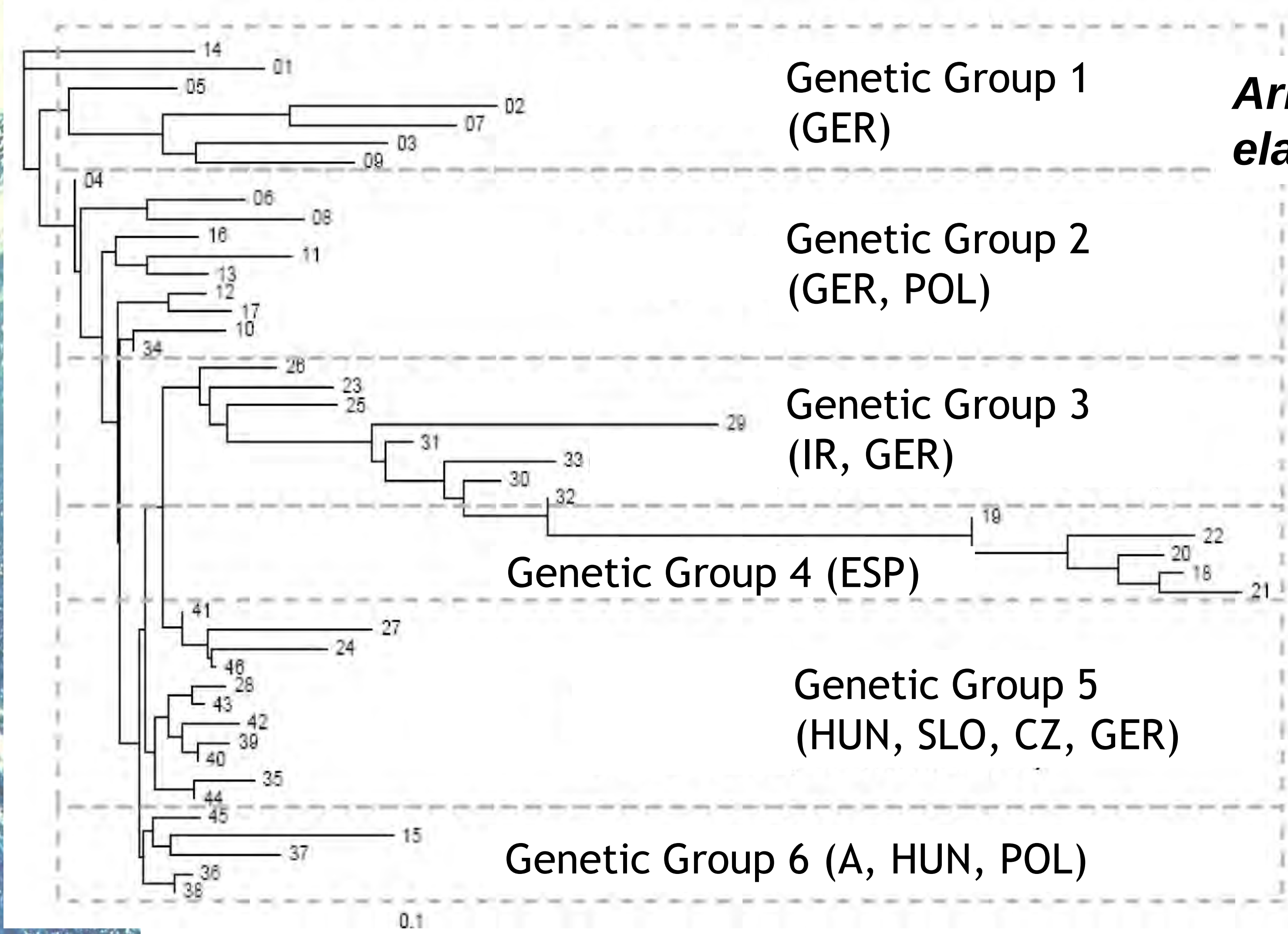
Arrhenatherum elatius



Distance decay

Michalski, SG; Durka, W; Jentsch, A; Kreyling, J; Pompe, S; Willner, E; Beierkuhnlein, C (2010) **Theoretical and Applied Genetics 120**, 1151-1162

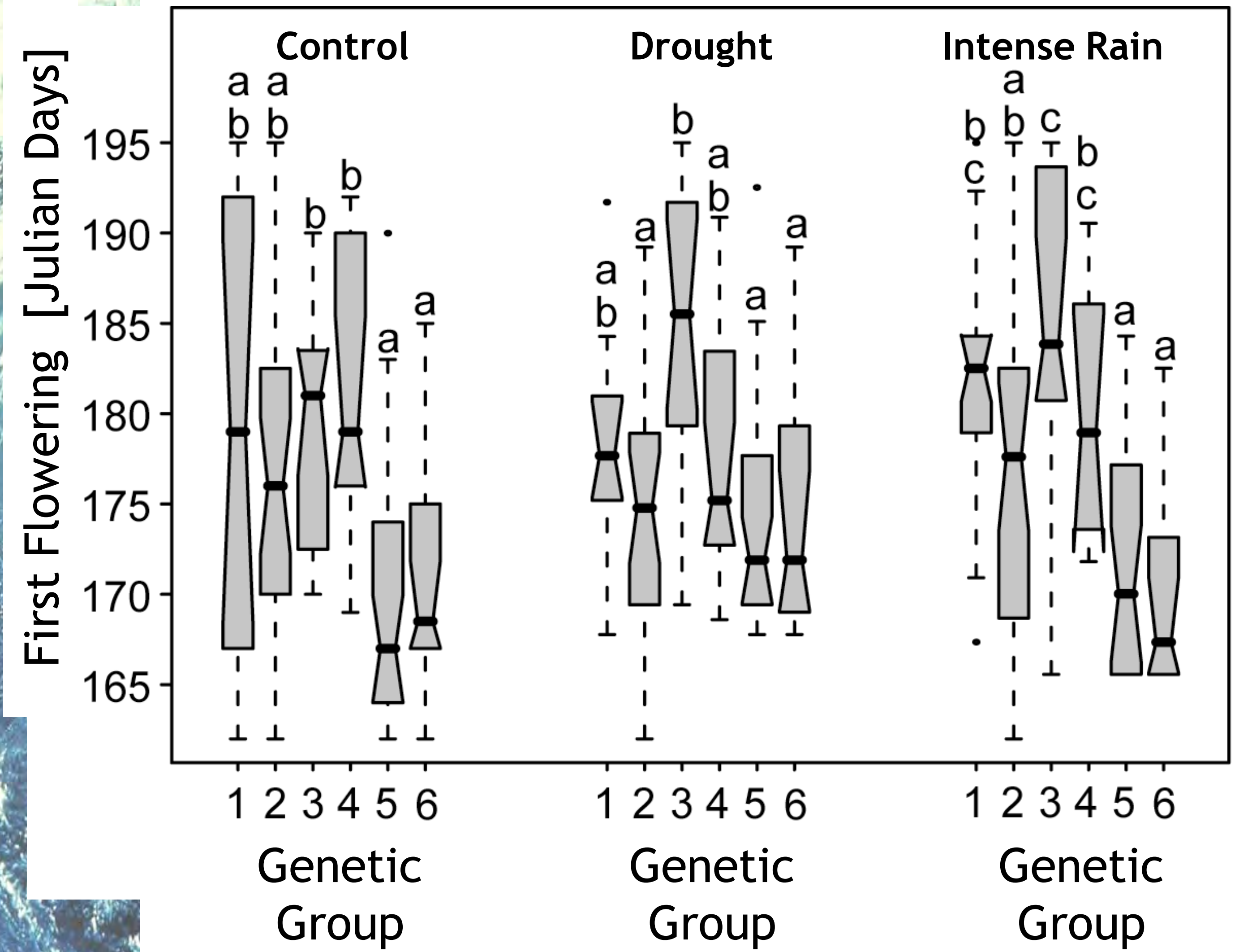
Experiments on Key Species



Arrhenatherum elatius

Michalski, SG; Durka, W; Jentsch, A; Kreyling, J; Pompe, S; Willner, E; Beierkuhnlein, C (2010) **Theoretical and Applied Genetics 120**, 1151-1162

Experiments on Key Species

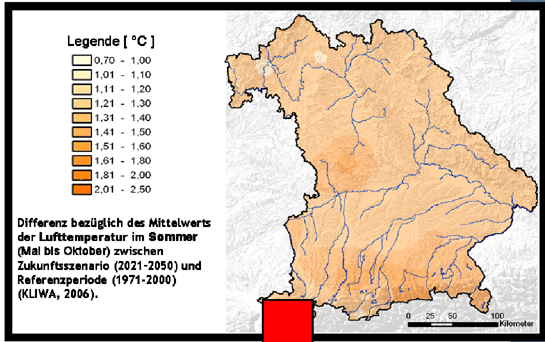


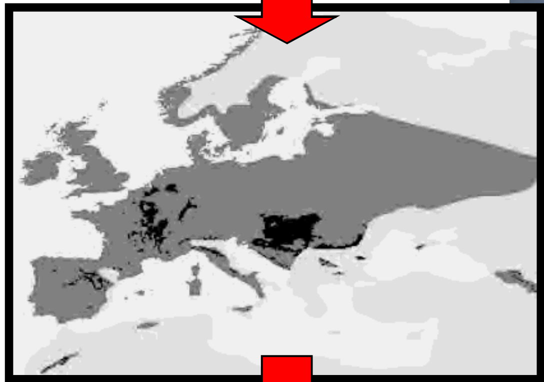
Arrhenatherum elatius

Genetic groups respond specifically when exposed to climate extremes

Experiments on Key Species

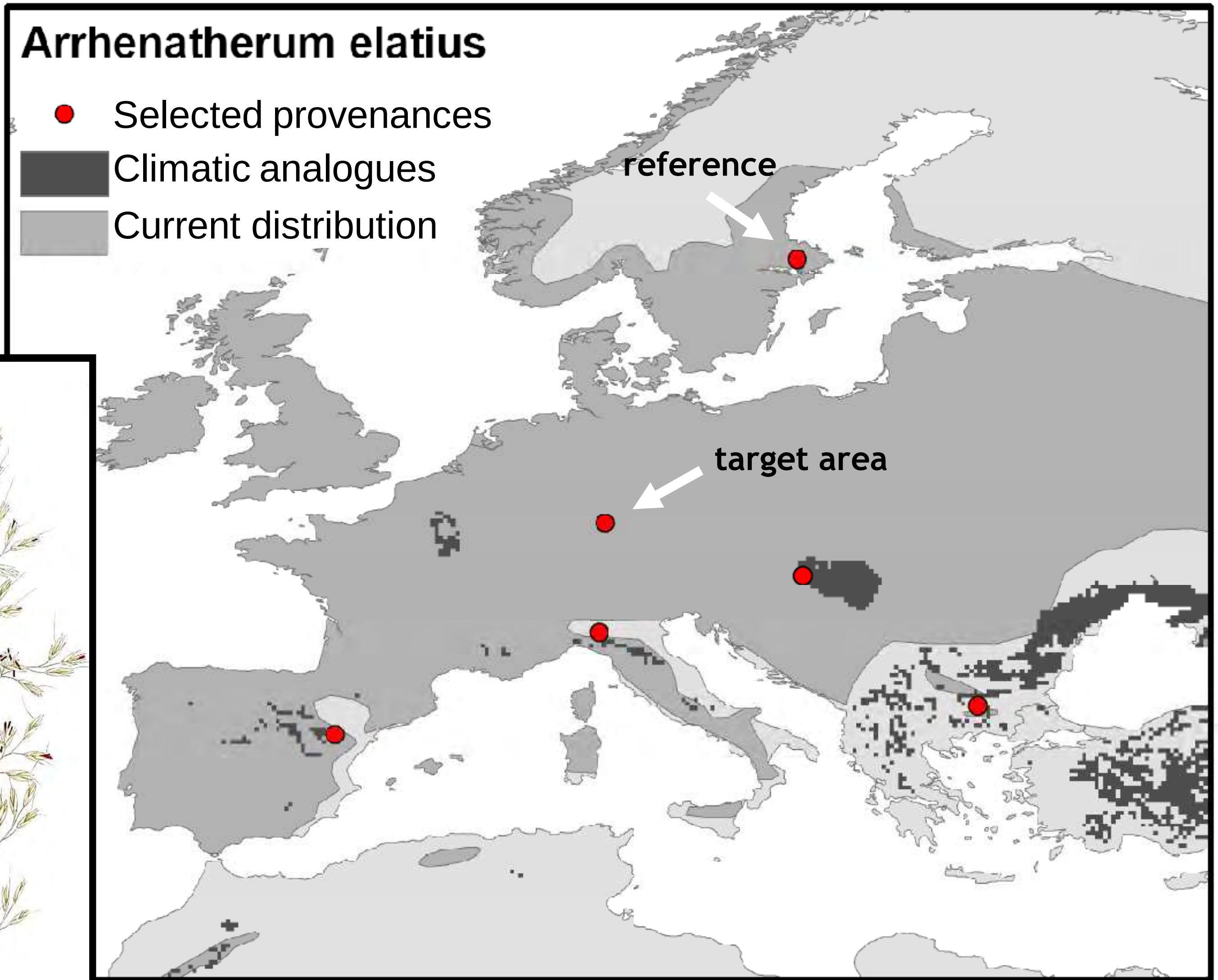
- Projection of future climatic conditions via regional climate models (A1B, REMO)
- Identification of regions with climate conditions (WORLDCLIM) similar to future projections for target area to select provenances from key species
- Experimental test of selected provenances exposed to drought and increased temperature.





Experiments on Key Species

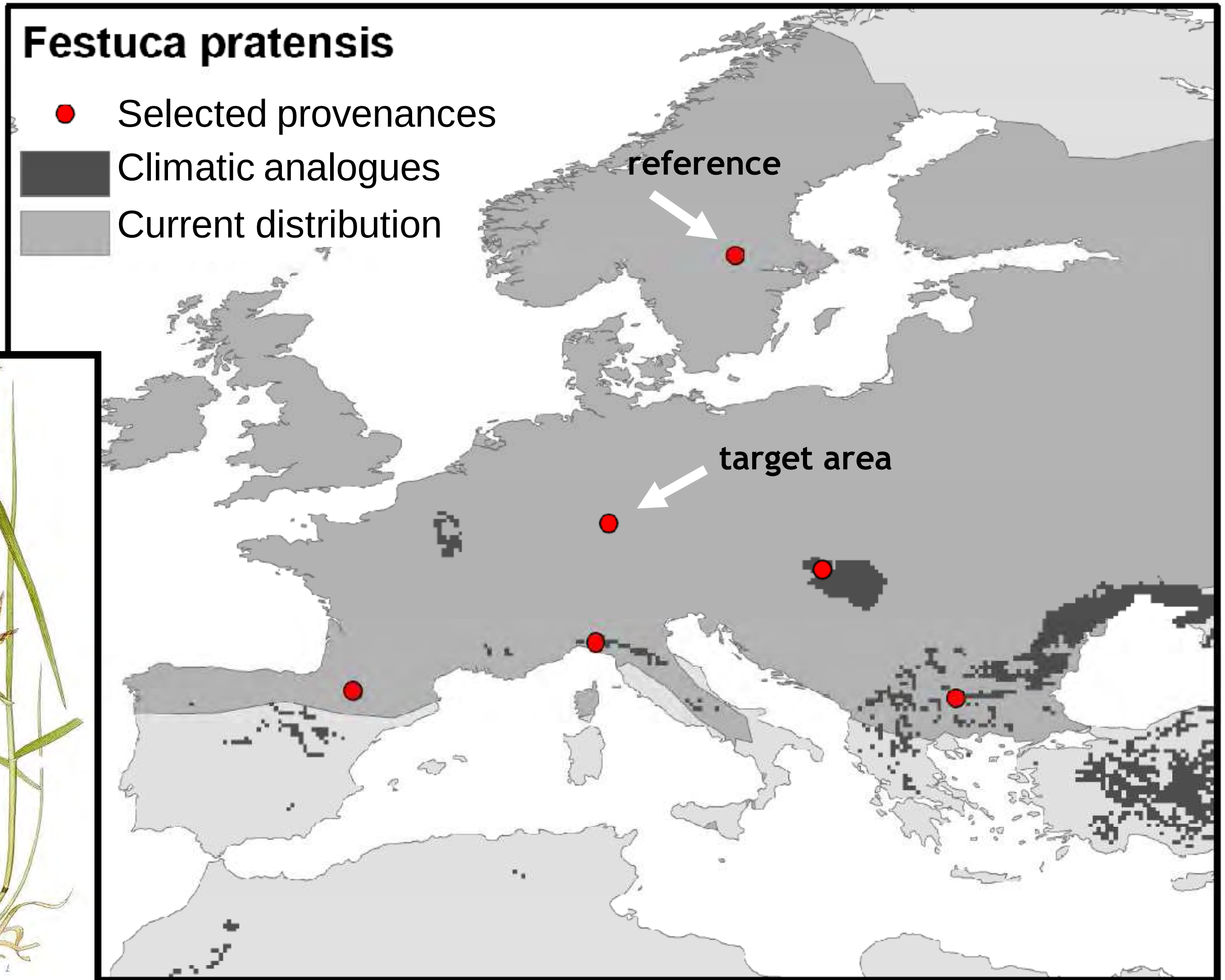
6 provenances



Climatic analogues in WORLDCLIM data base derived from calculations for the end of 21st cent. for the target area (Bayreuth, Germany) in Regional Climate Models (REMO; A1B scenario)

Experiments on Key Species

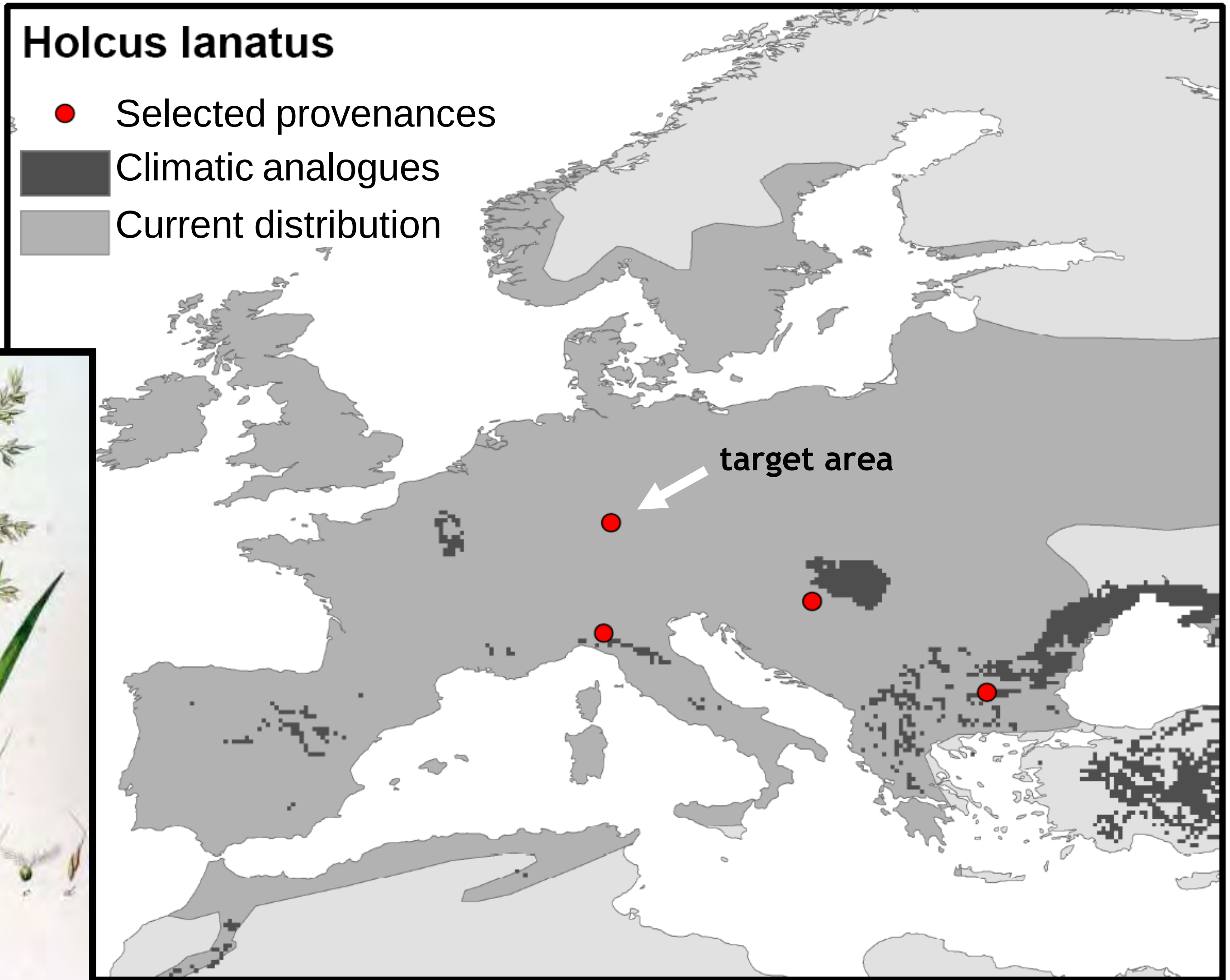
6 provenances



Climatic analogues in WORLDCLIM data base derived from calculations for the end of 21st cent. for the target area (Bayreuth, Germany) in Regional Climate Models (REMO; A1B scenario)

Experiments on Key Species

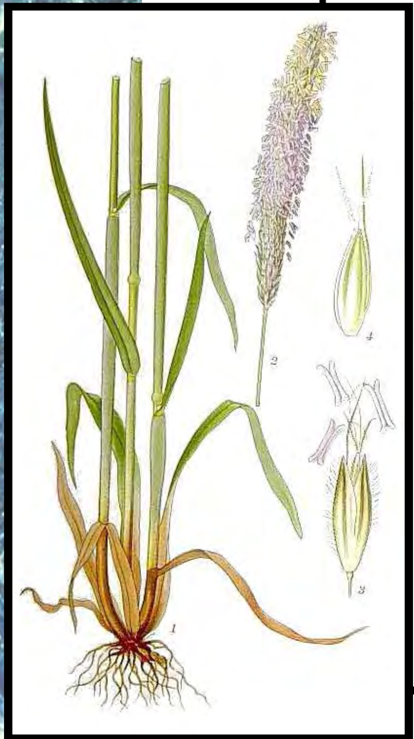
4 provenances

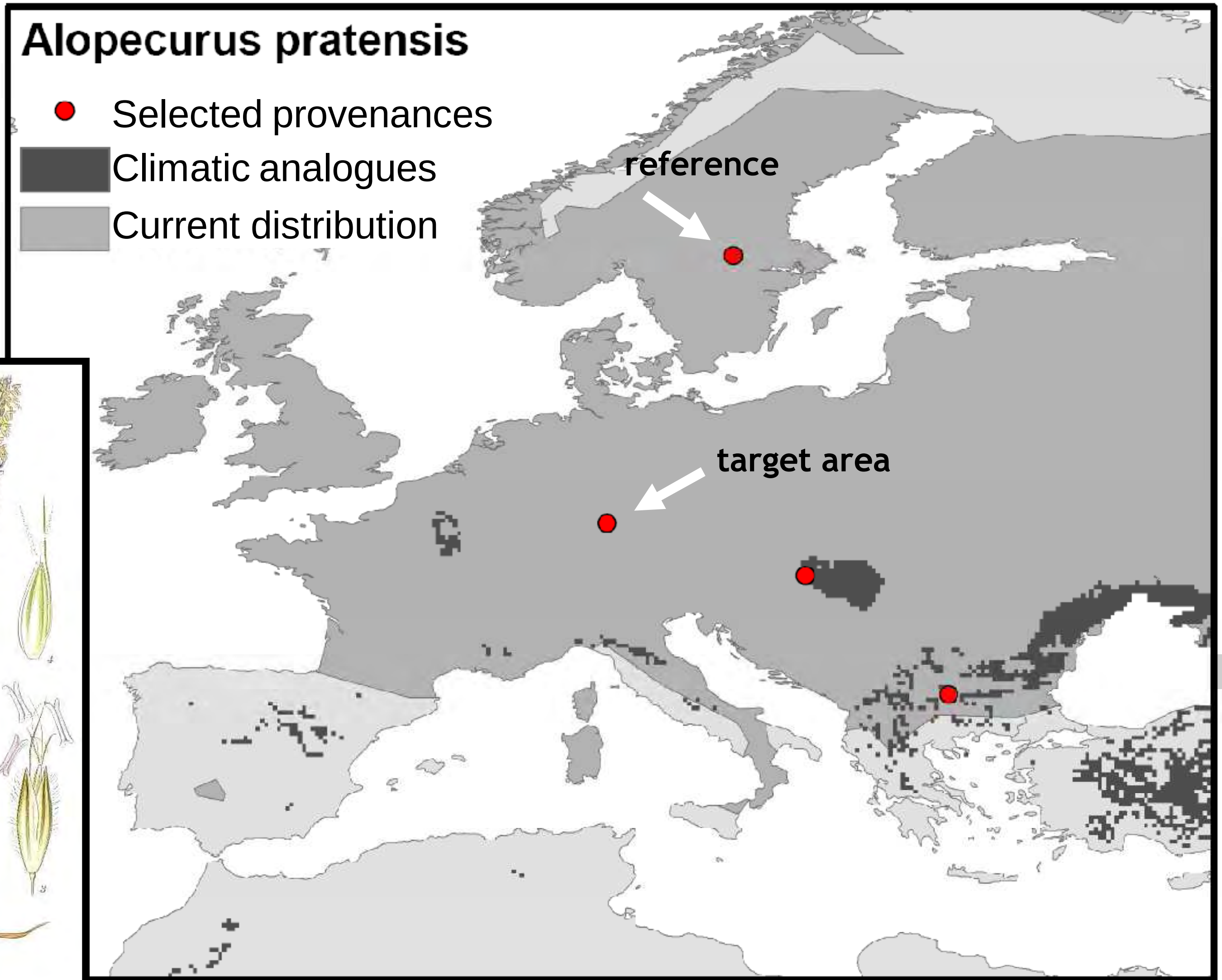


Climatic analogues in WORLDCLIM data base derived from calculations for the end of 21st cent. for the target area (Bayreuth, Germany) in Regional Climate Models (REMO; A1B scenario)

Experiments on Key Species

4 provenances





Climatic analogues in WORLDCLIM data base derived from calculations for the end of 21st cent. for the target area (Bayreuth, Germany) in Regional Climate Models (REMO; A1B scenario)

Experiments on Key Species

Plasticity and adaptive capacity of selected provenances of key grass species in the face of climatic extreme events

Experiments on Key Species

- 3 climate manipulations (treatments)
- 3 replications (houses) per treatment
- 7 nested replicates (potted plants) per house, species and provenance.

Warming	Drought	Drought & Warming	Control
Control	Drought & Warming	Drought	Warming
Drought	Control	Warming	Drought & Warming

60 m

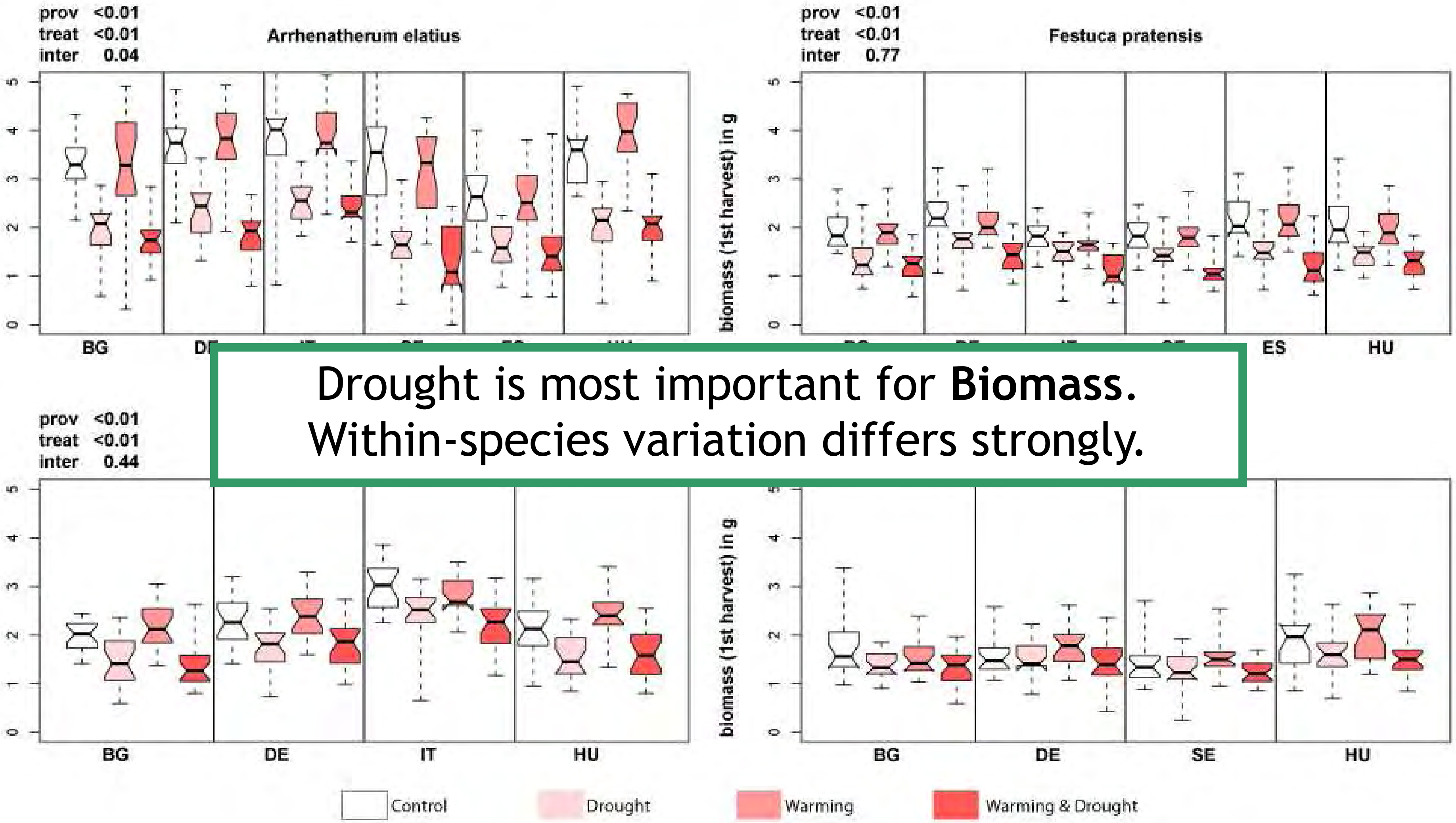
Control:
Irrigated twice a week according to daily 30-year average precipitation data

Drought (extreme event, May-June):
Adapted to species specific response. 19 days for *A. elatius*, 16 days for *H. lanatus,* 18 days for *F. pratensis,* and 18 days for *A. pratensis*

Warming (permanent):
Increase of average in-house temperature by 1.5 K with wind-shelters and dark floor

Warming & Drought:
Combined treatment

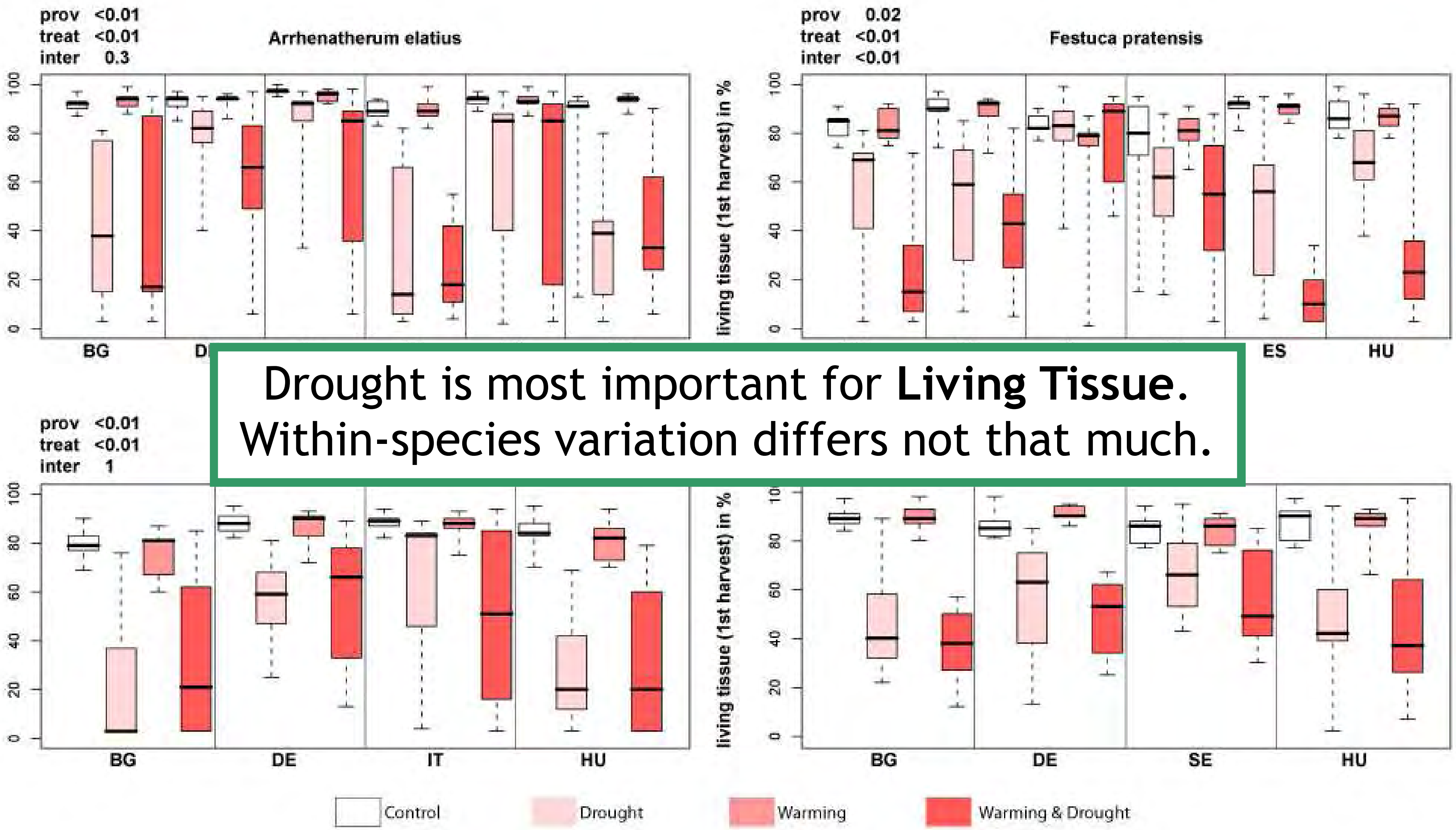
Experiments on Key Species



Drought is most important for **Biomass**.
Within-species variation differs strongly.

Biomass production (**first harvest**) until ten days after the end of the drought manipulation with ANOVA results of linear mixed models.

Experiments on Key Species

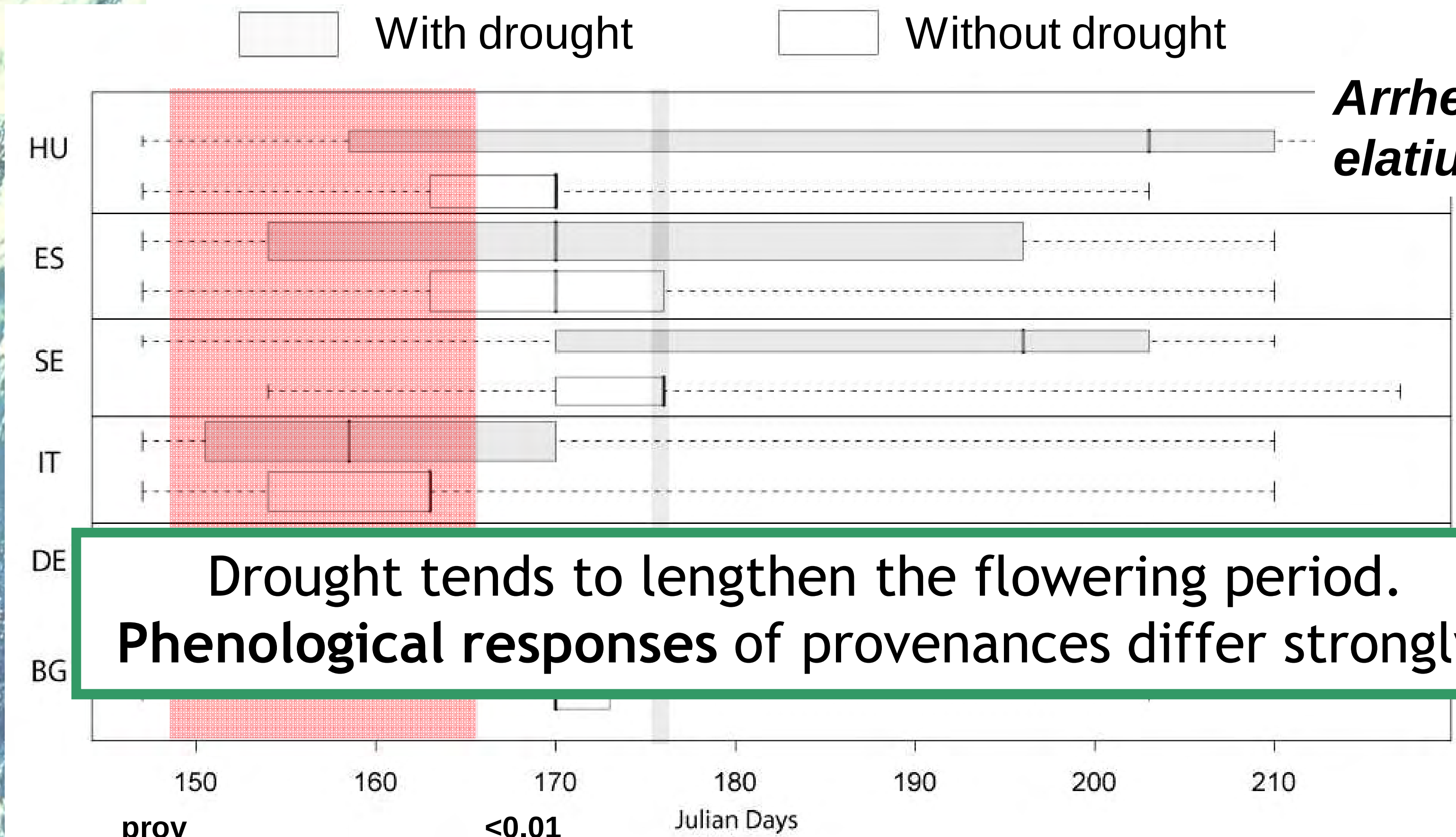


Drought is most important for **Living Tissue**.
Within-species variation differs not that much.

Beierkuhnlein, C., Kreyling, J., Thiel, D., Jentsch, A. (2010) Species-specific and provenance-specific responses of key grass species to extreme climatic events. Journal of Ecology, prov. accepted.

Experiments on Key Species

Arrhenatherum elatius



Drought tends to lengthen the flowering period.
Phenological responses of provenances differ strongly.

prov	**<0.01**
warming	**0.2**
drought	**<0.01**
prov:warming	**0.2**
prov:drought	**<0.01**
warming:drought	**1**
prov:warming:drought	**0.2**

Onset of flowering

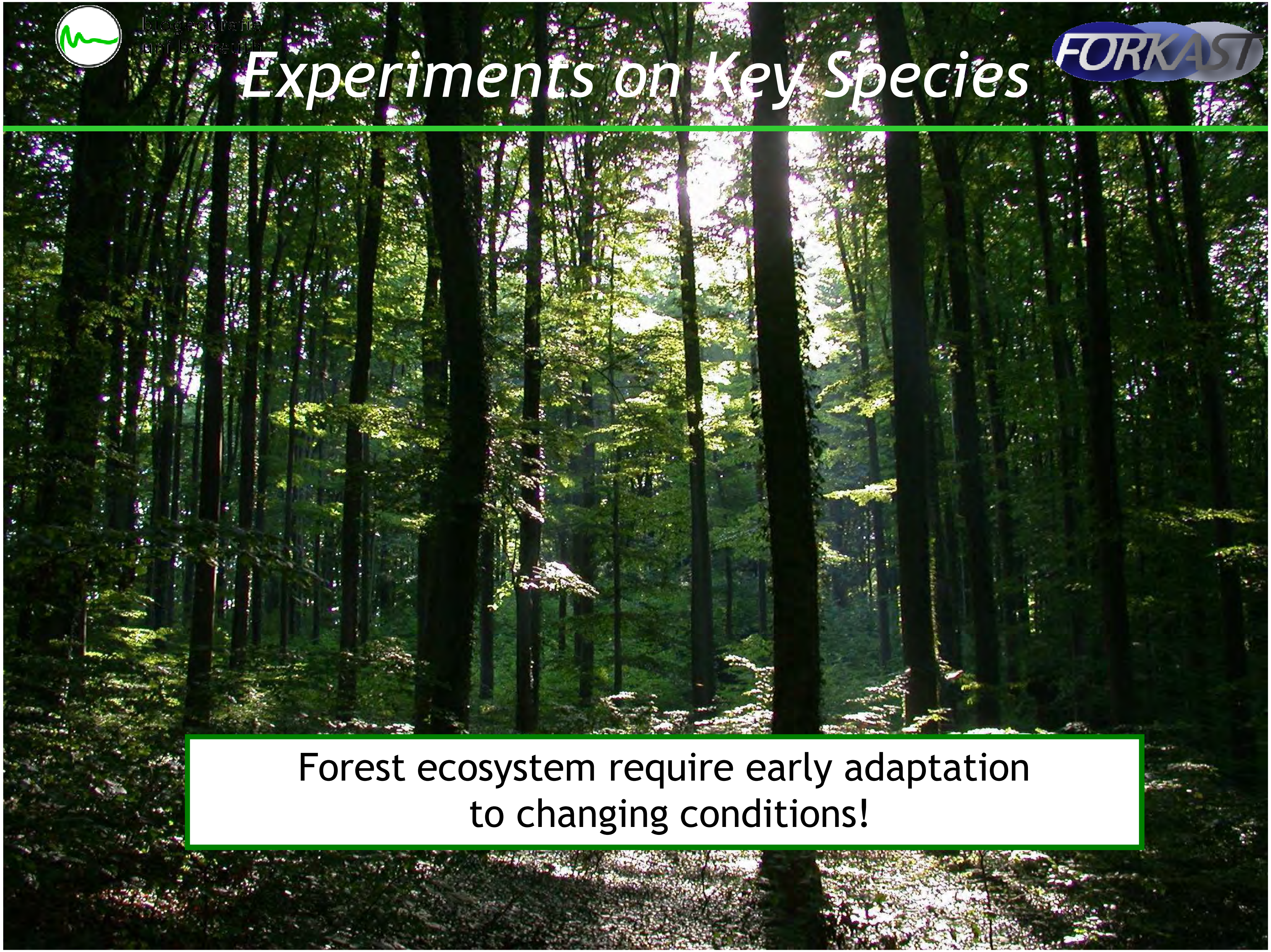
Earliest day BBCH-code 59 occured

Experiments on Key Species

For European key grass species:

- Extreme drought creates **provenance-specific responses** in biomass, necrotic tissue and phenology.
- Hardly any significant warming effects.

Experiments on Key Species

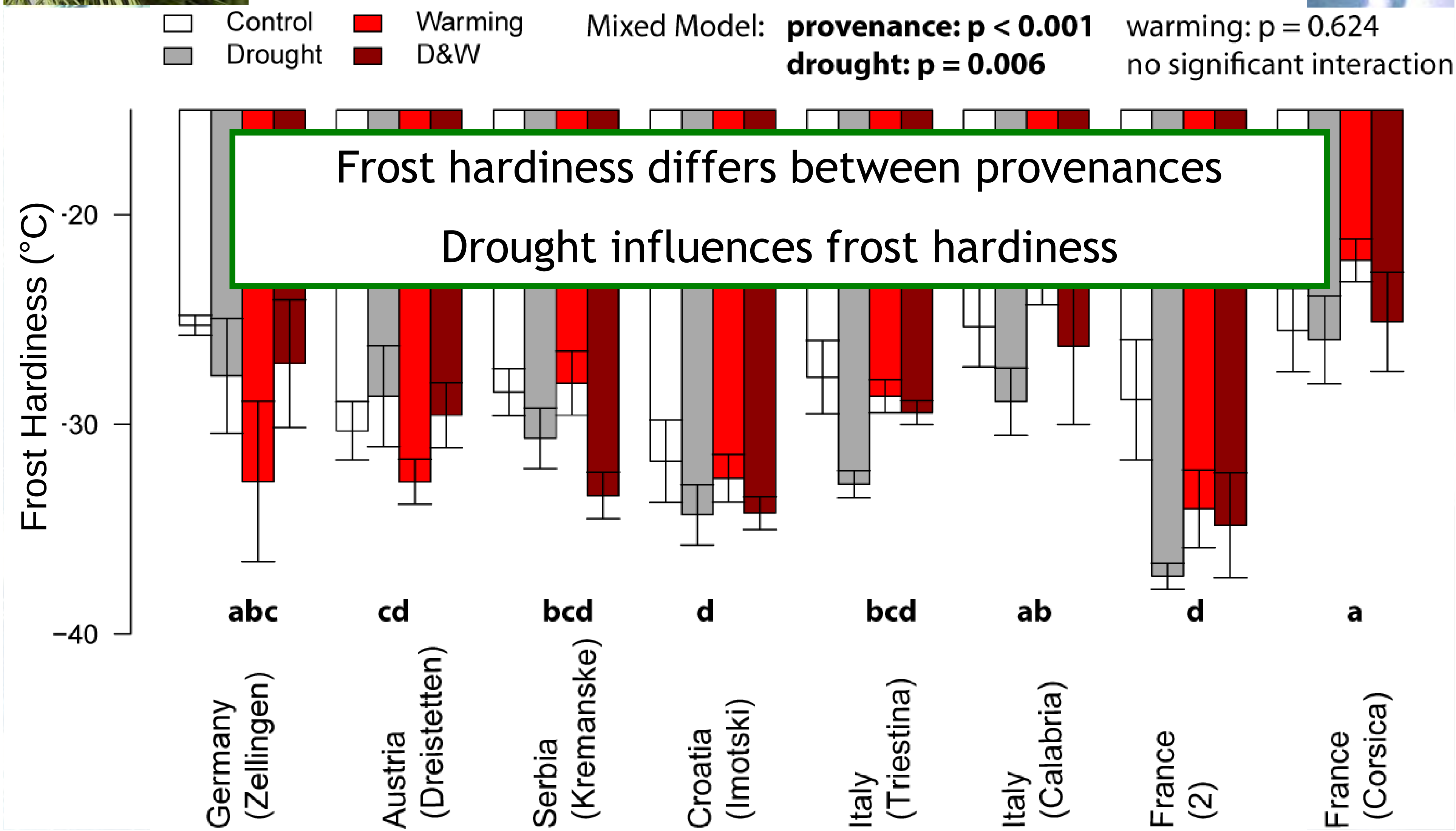


Forest ecosystem require early adaptation
to changing conditions!

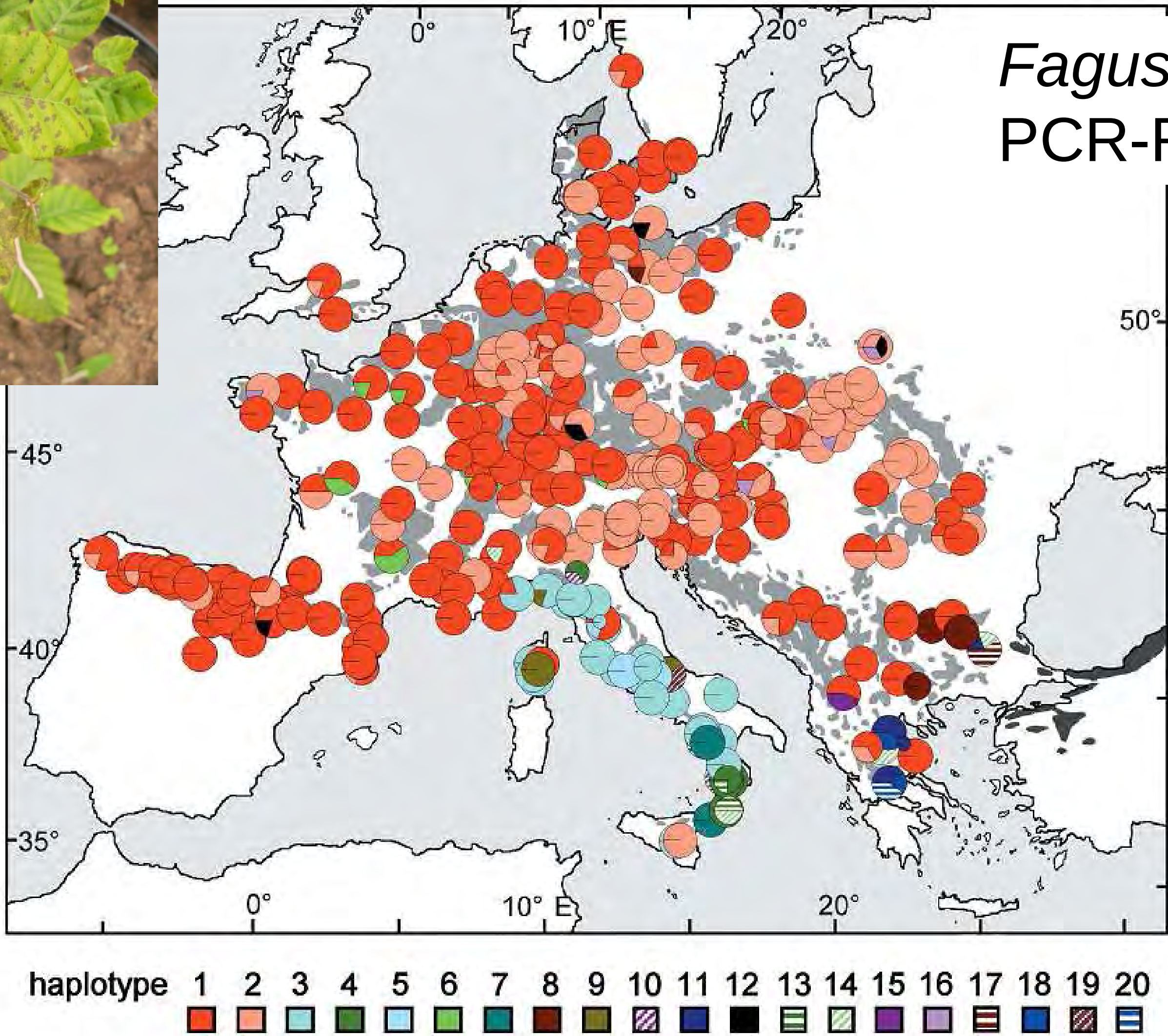
Experiments on Key Species

Frost hardiness of *Pinus nigra*

Relative Electrolyte Leakage;
frost hardiness = LT50



Experiments on Key Species

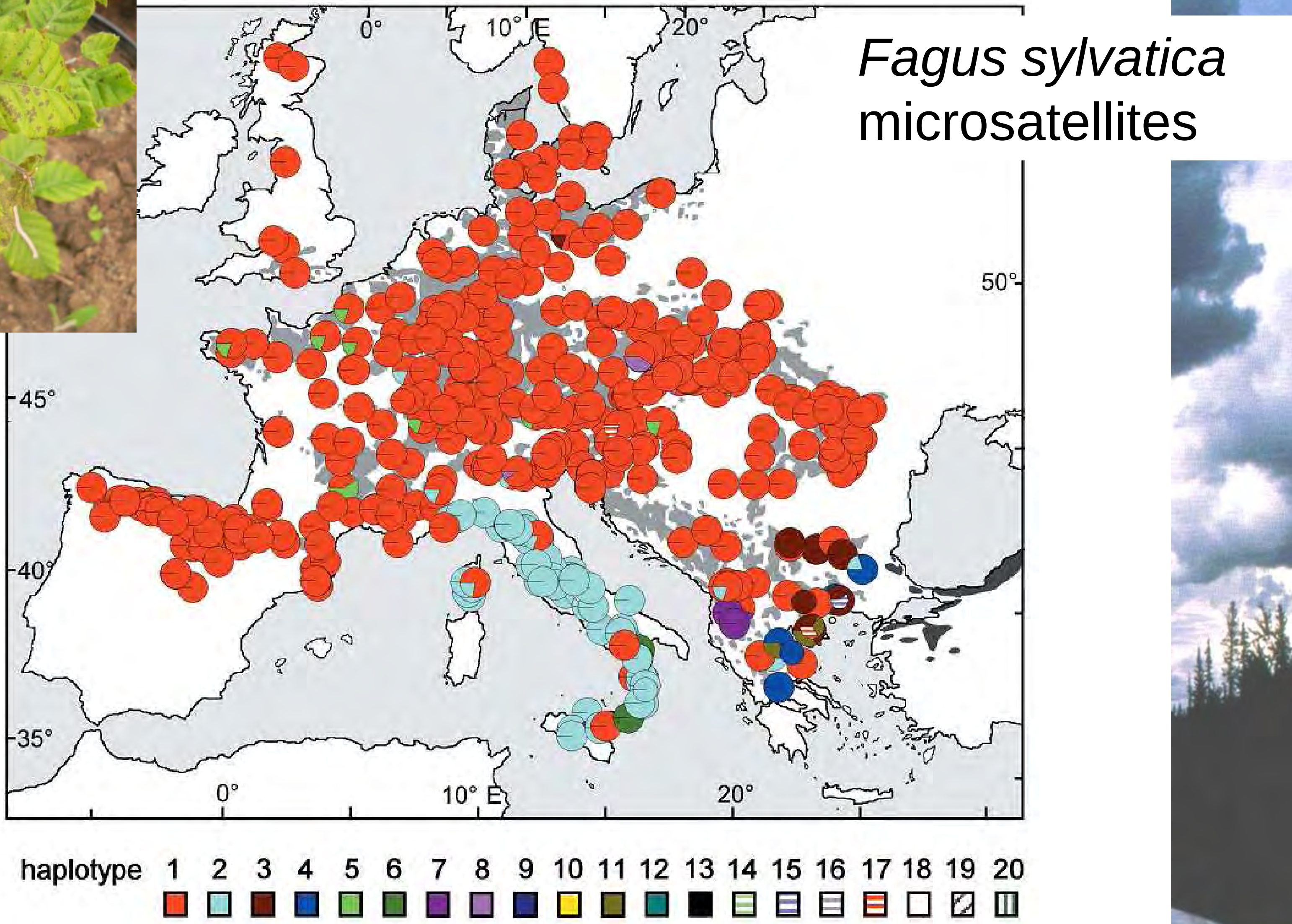


Fagus sylvatica
PCR-RFLP

chloroplast haplotypes detected using polymerase chain reaction–restriction fragment length polymorphism (PCR-RFLP)

Magri et al. 2006 New Phytologist

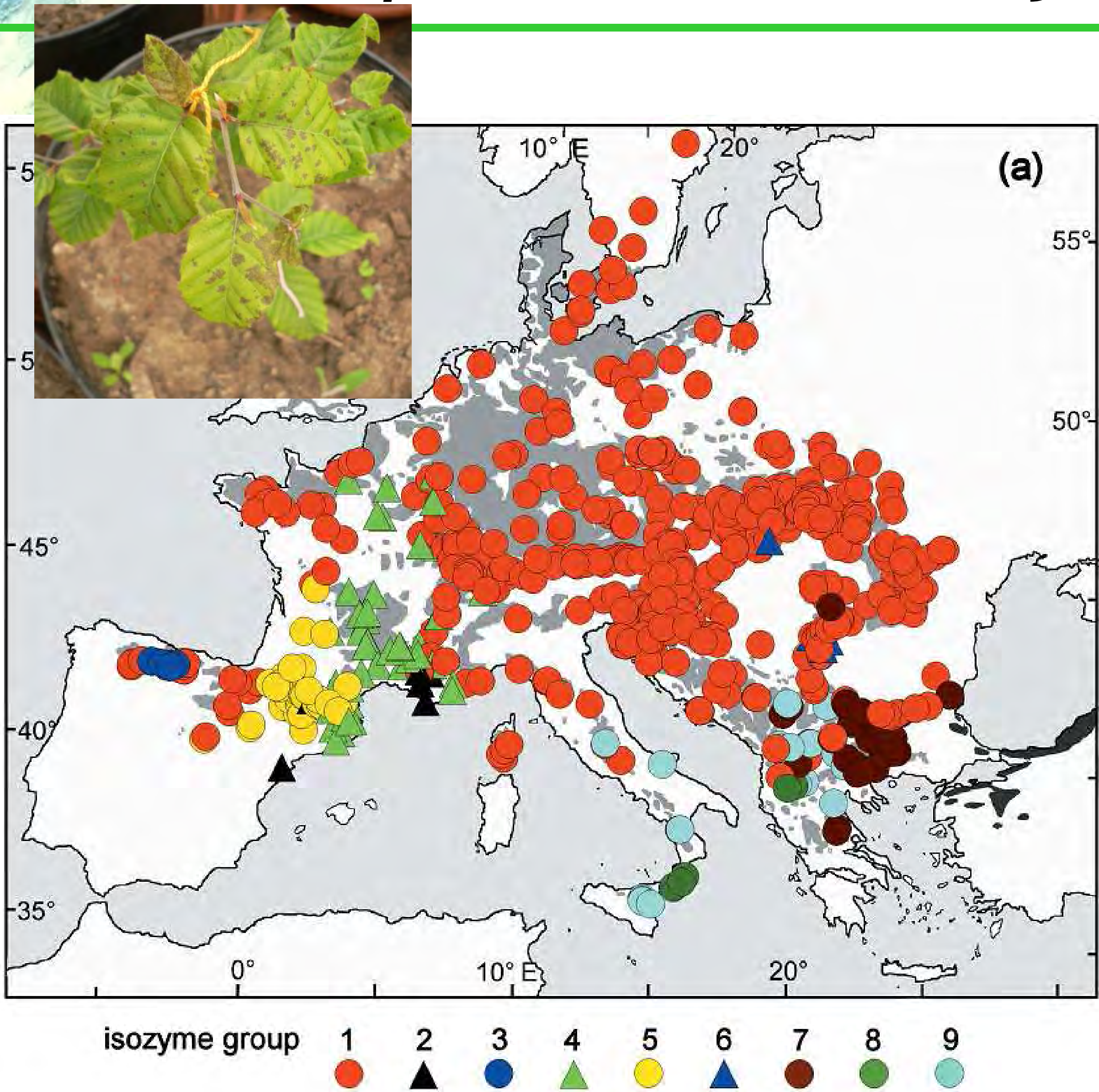
Experiments on Key Species



Magri et al. 2006 New Phytologist

Experiments on Key Species

Fagus sylvatica
isozymes



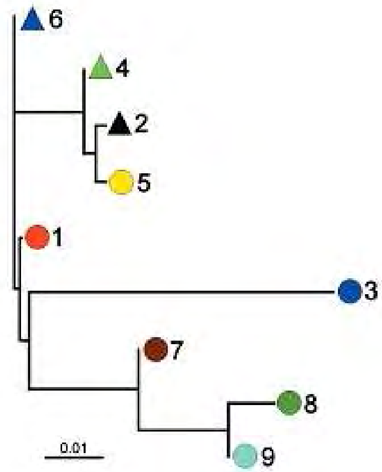
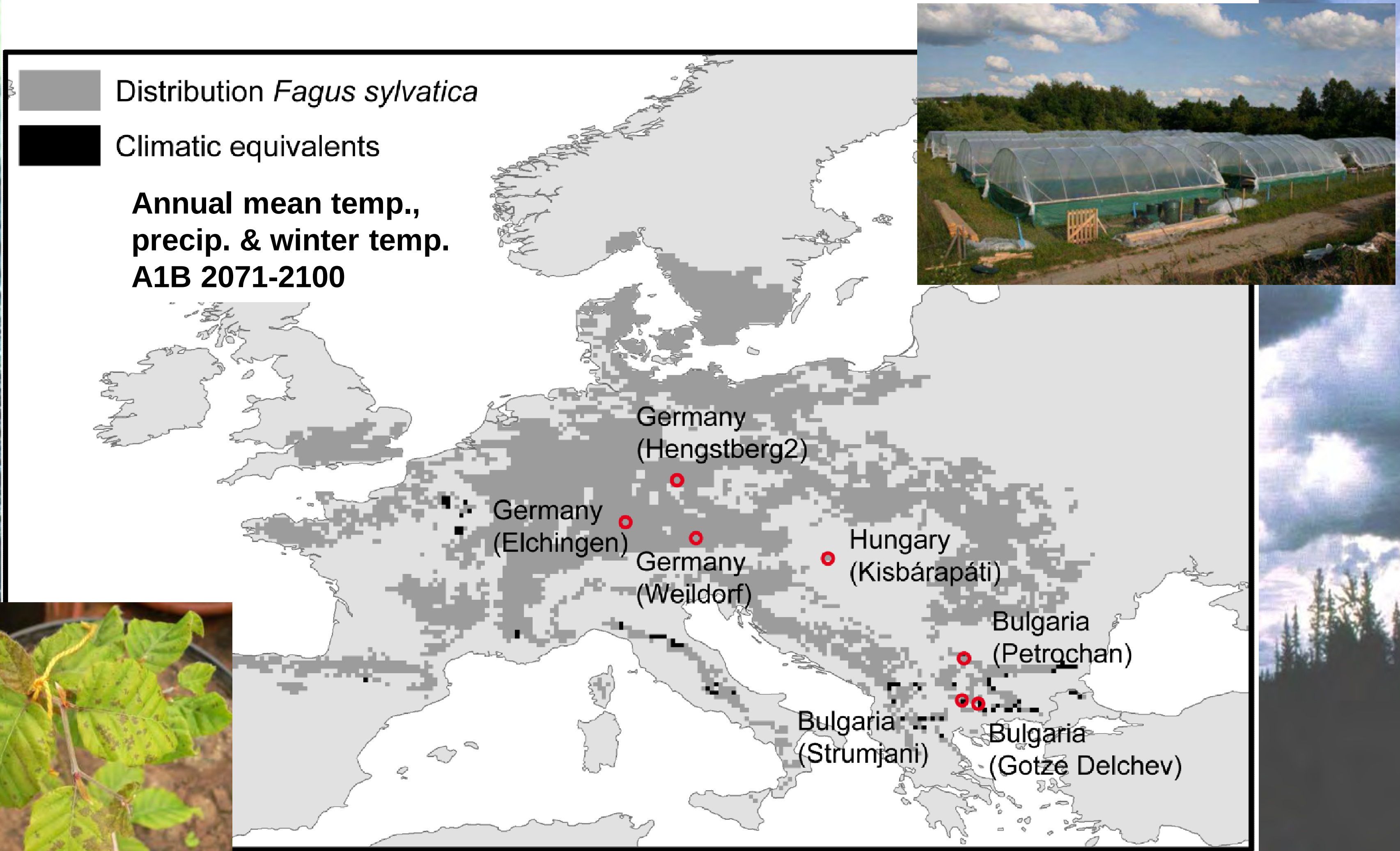


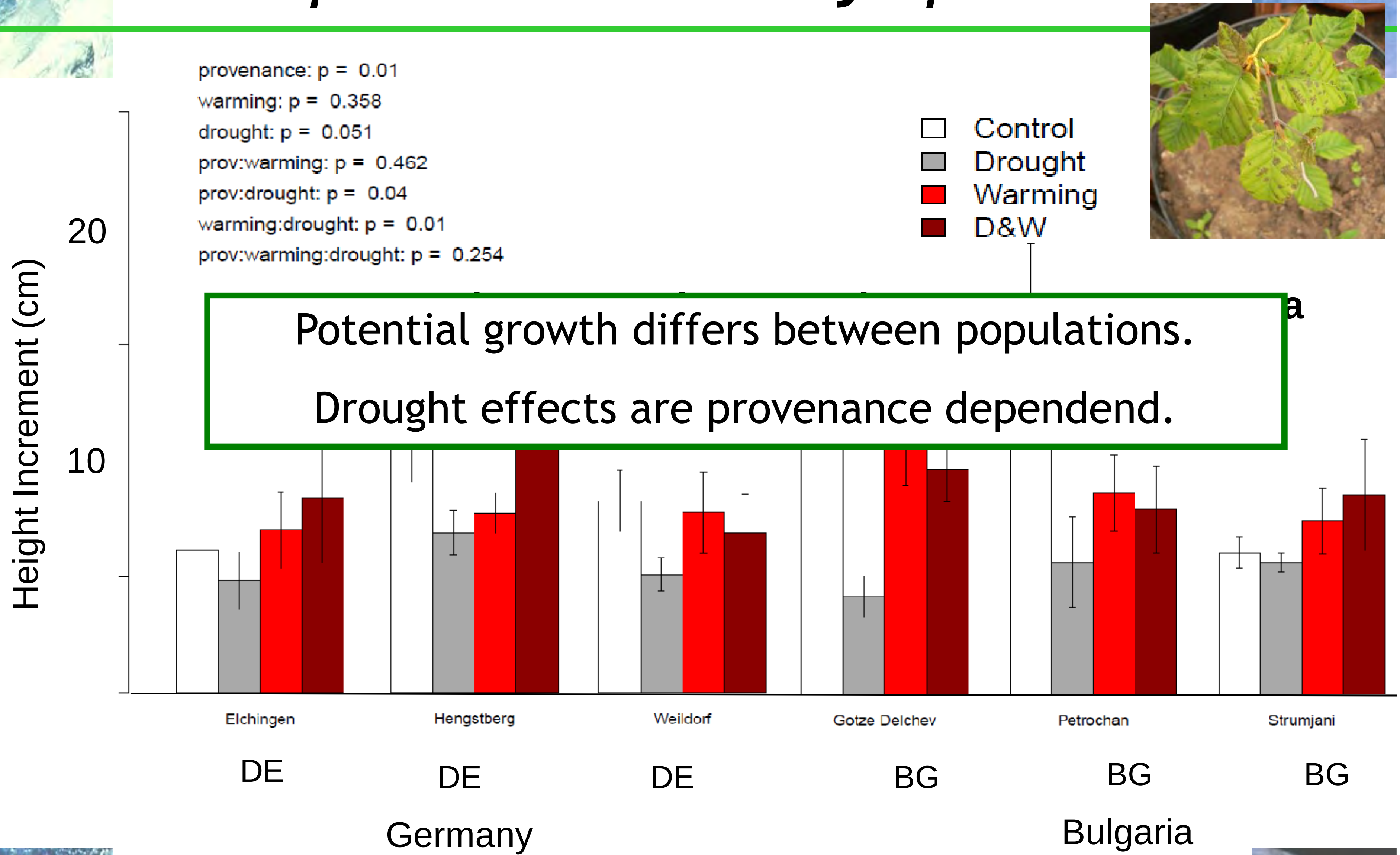
Fig. 6 Spatial analysis of variance (SAMOVA) on isozyme data. (a) geographical distribution of groups; (b) phylogenetic tree obtained using the neighbour-joining approach on the F_{CT} distance matrix for SAMOVA isozyme groups.

Magri et al. 2006 New Phytologist

Experiments on Key Species



Experiments on Key Species



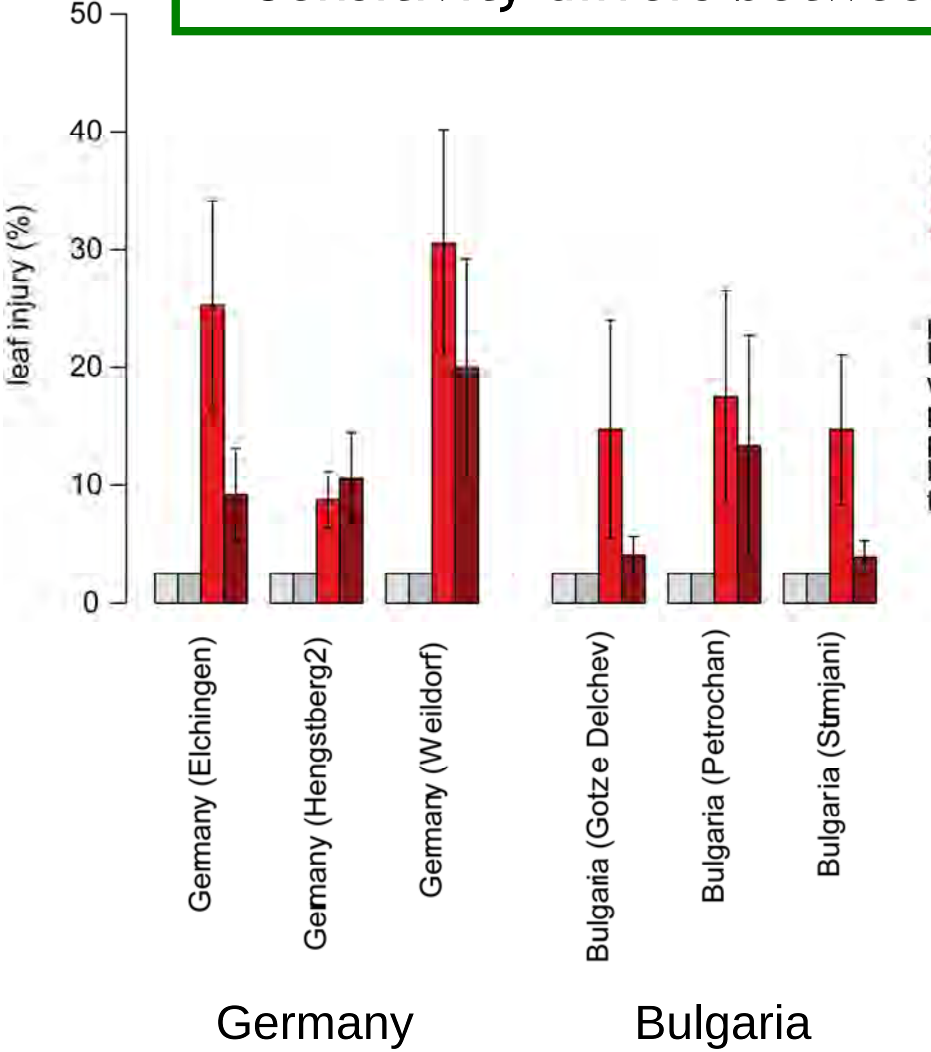
Potential growth differs between populations.

Drought effects are provenance dependend.

Experiments on Key Species

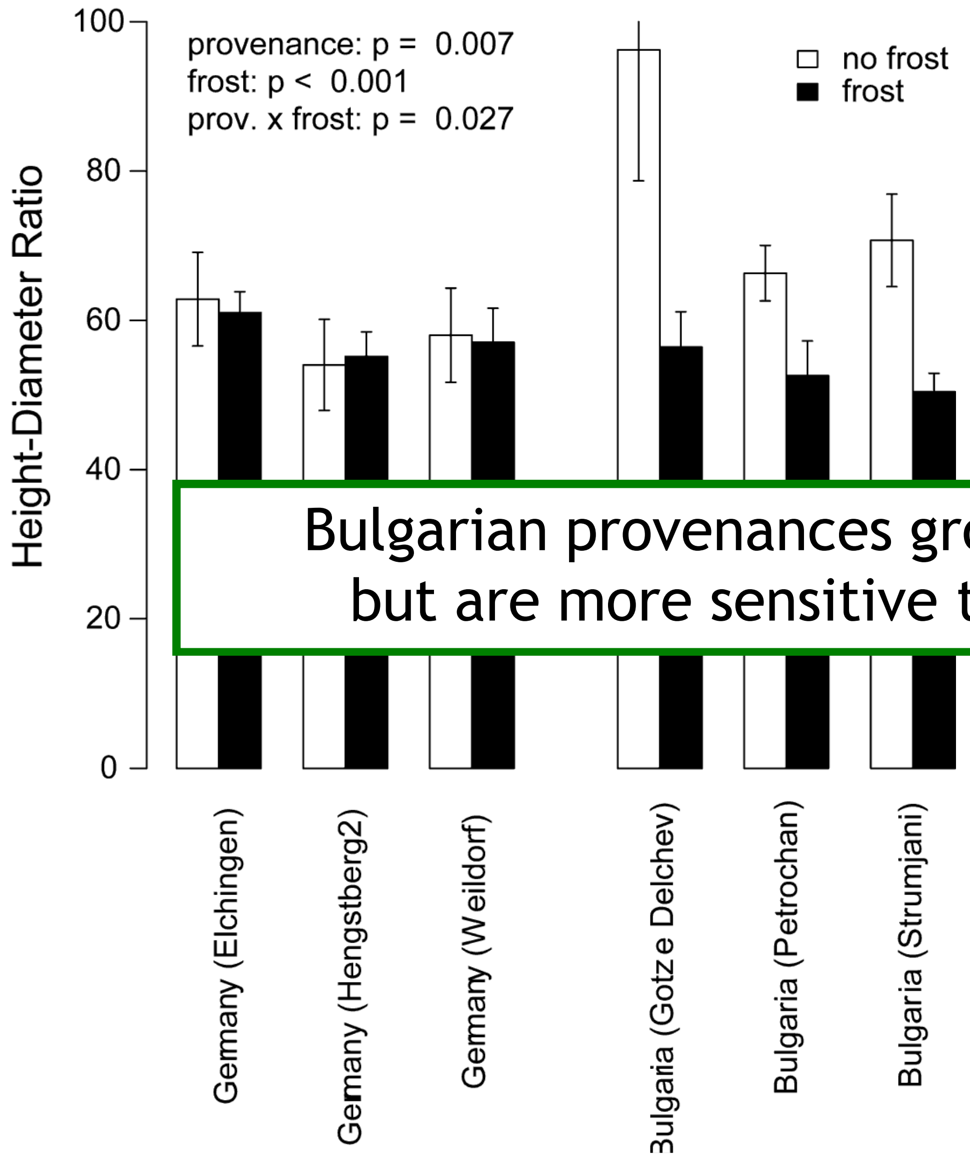
Simulation of late frost in May in freezing containers

Sensitivity differs between provenances



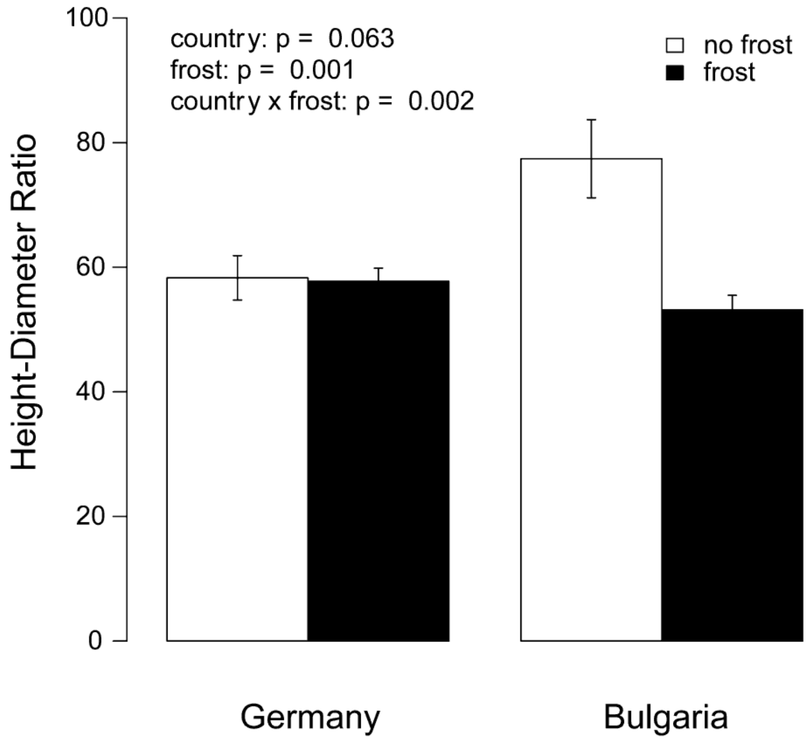
Experiments on Key Species

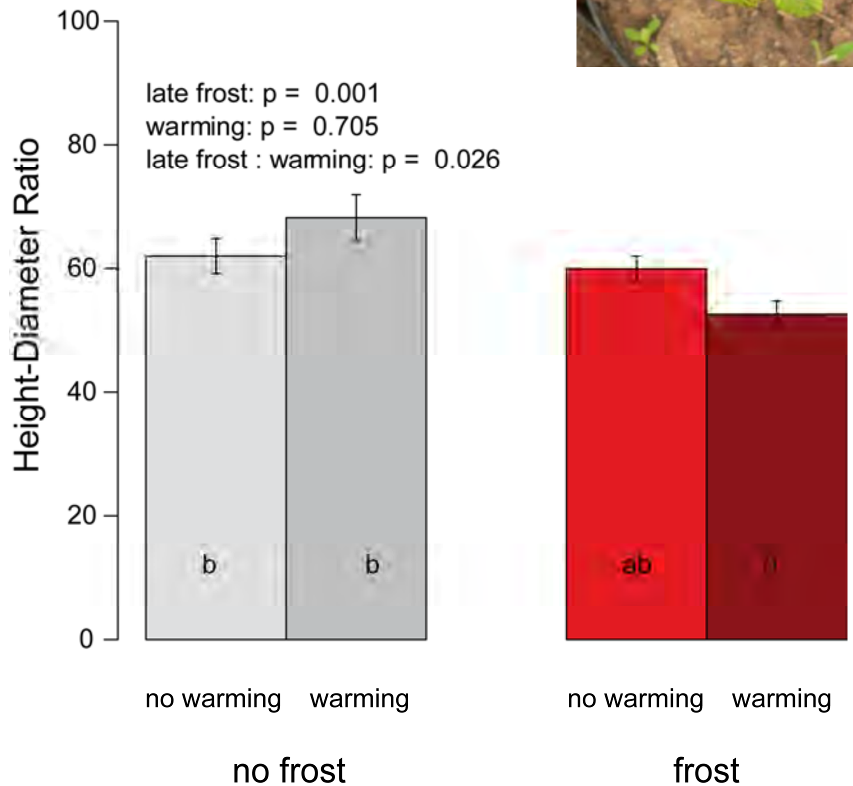
Fagus sylvatica



Bulgarian provenances grow taller
but are more sensitive to frost

Experiments on Key Species





Bulgarian provenances grow taller but are more sensitive to frost

Frost has stronger effects when combined with warming

Structure

1 Ecology of Climatic Extremes

2 What is Extreme ?

3 Within-Species Variance and Limits of Projection

4 Experiments on Key Species

5 Consequences and Risks

Climate Envelopes

- *Climate envelope models may over-estimate the plasticity of species with locally adapted populations in face of climate change.*

Experiments

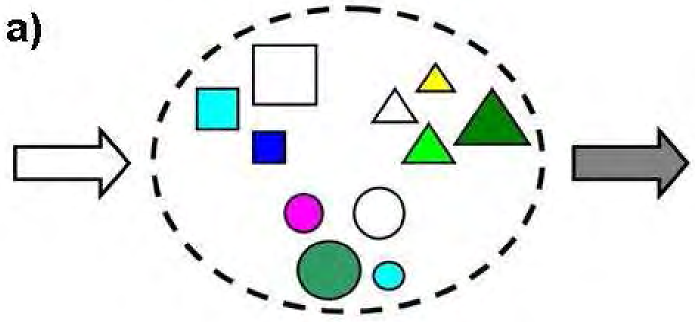
- *Experiments are always somehow artificial, but they are the only way to test hypotheses and to gain insights into novel and hitherto not existing environmental conditions.*

Experiments

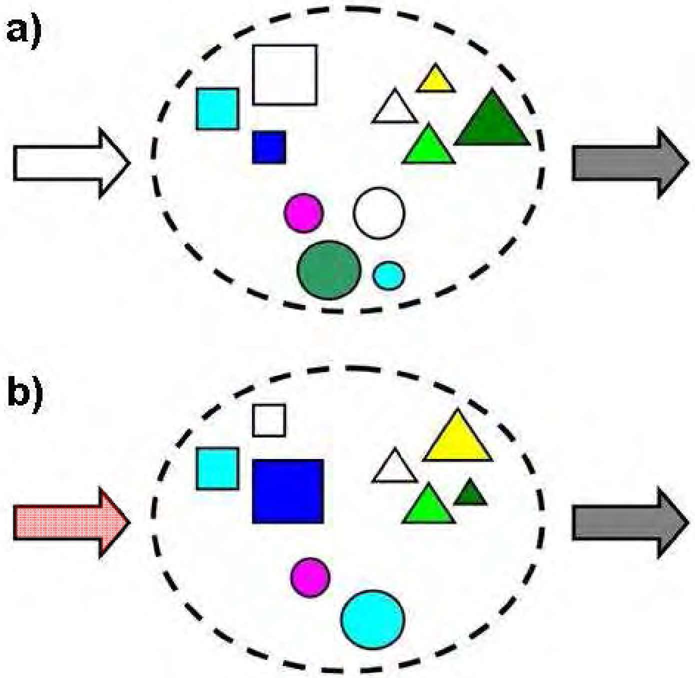
Die „*Pflanzengeographie (…) setzt eine genaue Kenntnis der Lebens-bedingungen der Pflanze voraus, die nur ein Experiment verschaffen kann.*“

Andreas Franz Wilhelm **Schimper** (1856-1901)

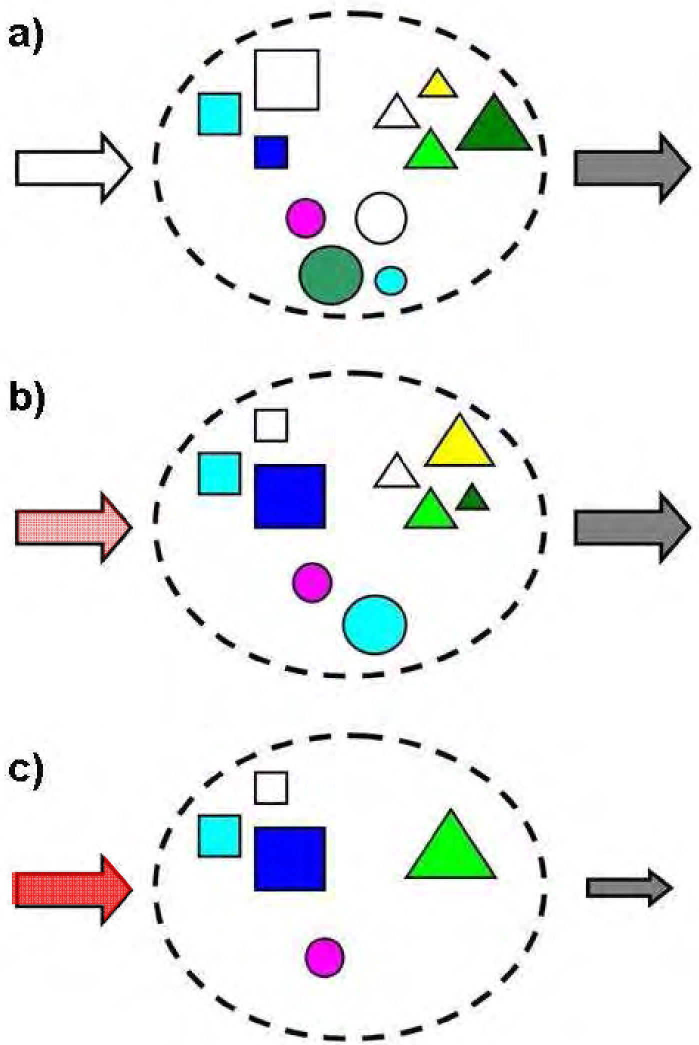
Diversity & Functioning



Diversity & Functioning



Diversity & Functioning



Insurance Effect

Phenotypic diversity may buffer the effects of climate change and extreme events

Diversity & Functioning

Projections on the **ecological consequences of climatic extremes** have to consider

- *Biodiversity*
- *Community composition*
- *Species identity*
- ***Genetic diversity within species***

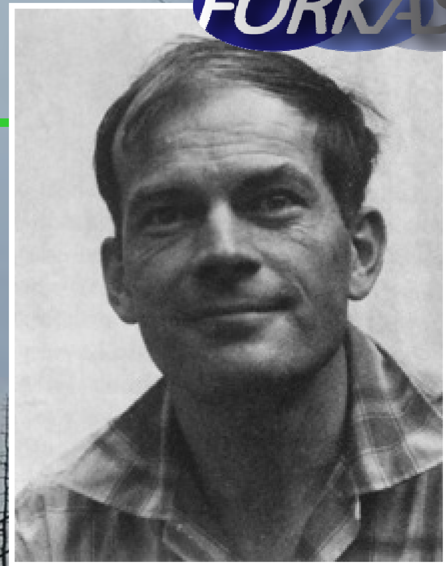
Management Options ?

Selection of provenances is a **potential tool for adaptation** in face of increased extreme events

Phenotypically **mixed populations** could support the insurance of ecosystem functions.

However, **conseqences of assisted migration** of phenotypes are unclear.

We need more **large scale provenance trials.**



"To do science, is to search for repeated patterns, not simply to accumulate facts"

Robert MacArthur, 1972

Thanks