Demographic performance of European tree species at their hot and cold climatic edges.

Managing Forests in the 21st century , Potsdam PIK, 4/04/20

Kunstler, G., Guyennon A., Reineking, B., Childs D. Z., Dahlgren J., Kändler, G., Lehtonen, A., Ratcliffe, S., Ruger, N., Ruiz-Benito, P., Salguero-Gomez, R., Thuiller, W., Wirth, C., Zavala, M. A., and **sAPROPOS group** sDIV

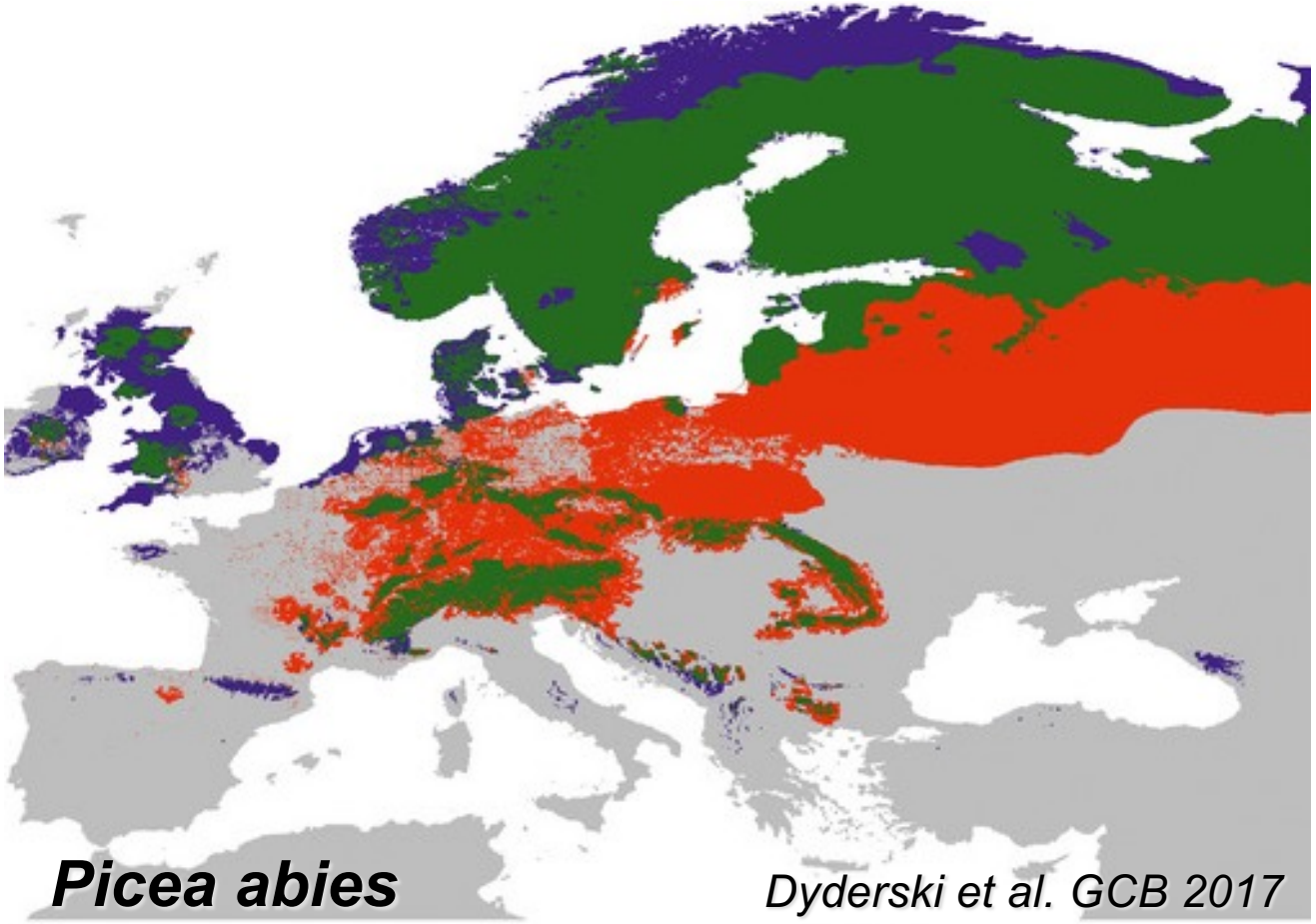
INRAE

LESSEM
Grenoble

REFORCE

Forest response to climate change and SDMs

SDM predictions of changes in species distribution



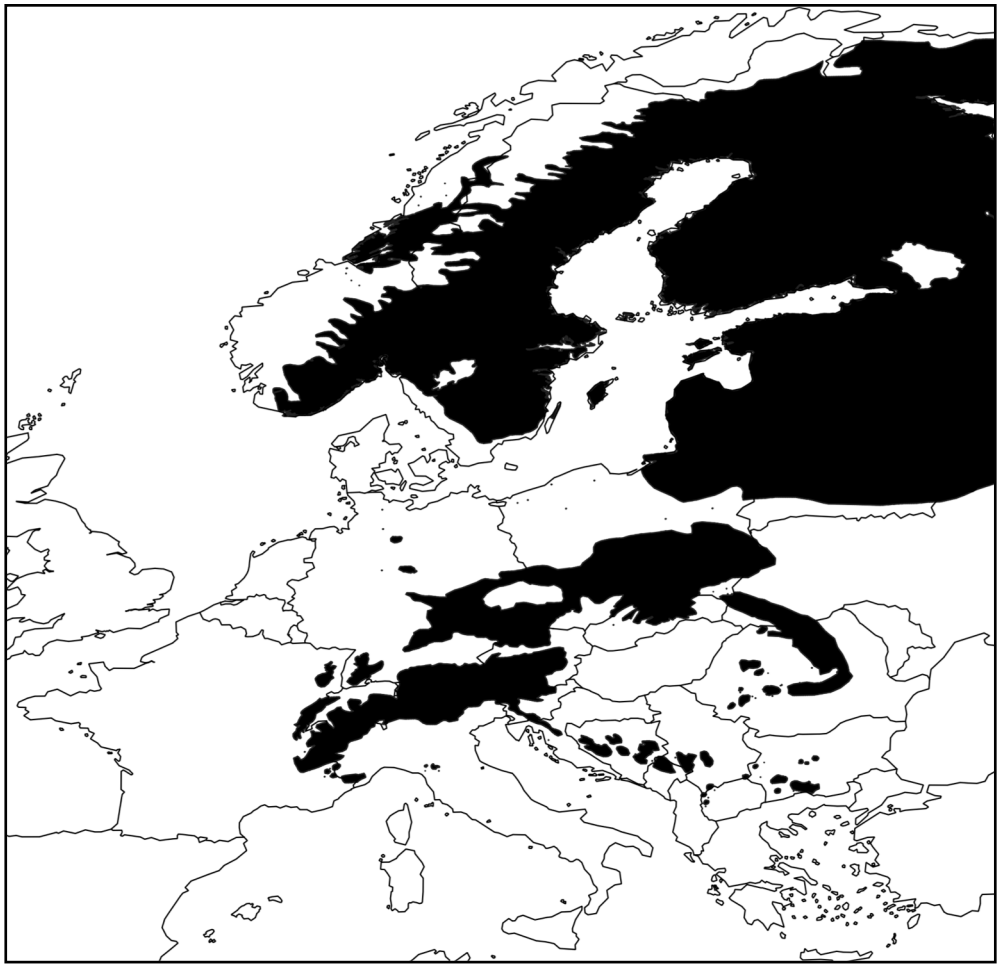
Picea abies

Dyderski et al. GCB 2017

Management needs forecasts on population dynamics

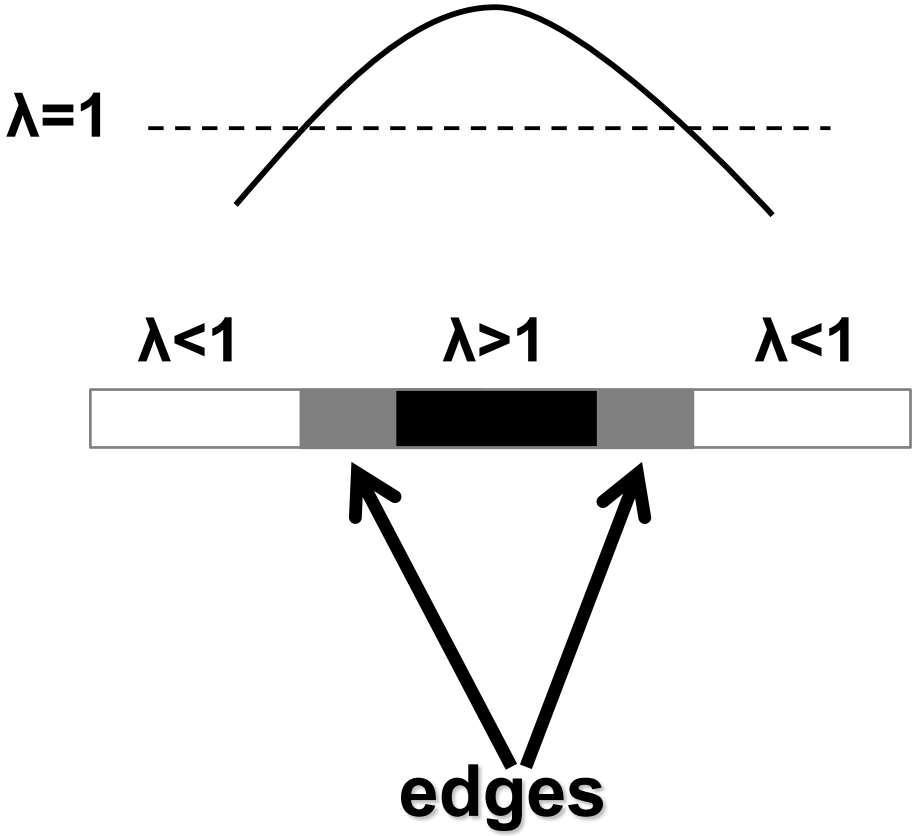
Species distribution and demography

Distribution



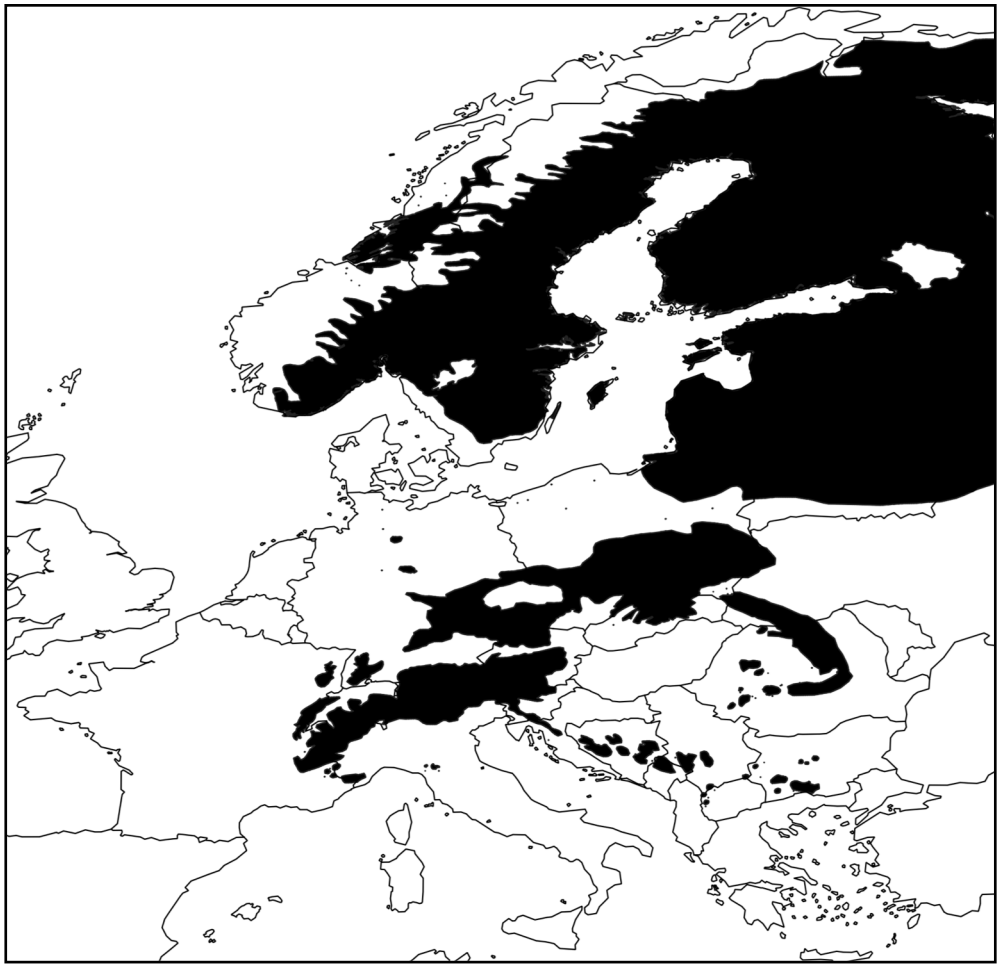
Picea abies

Population growth rate



Species distribution and demography

Distribution



Picea abies

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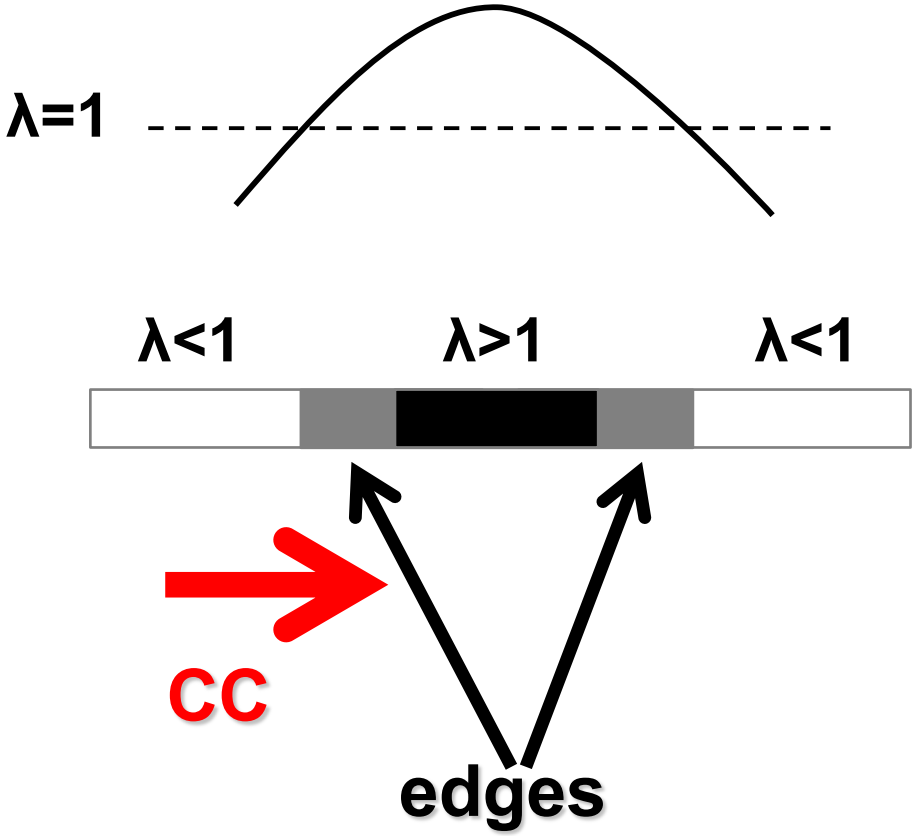
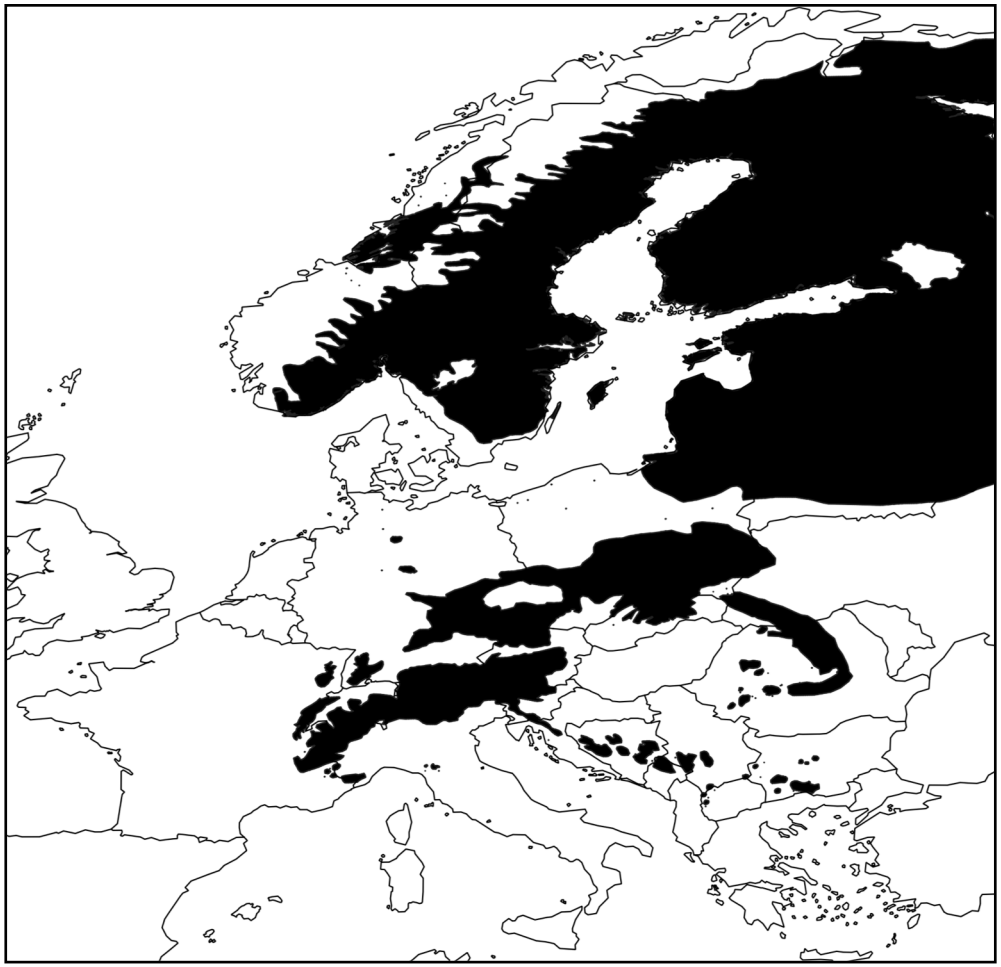


Species distribution and demography

Distribution



Picea abies

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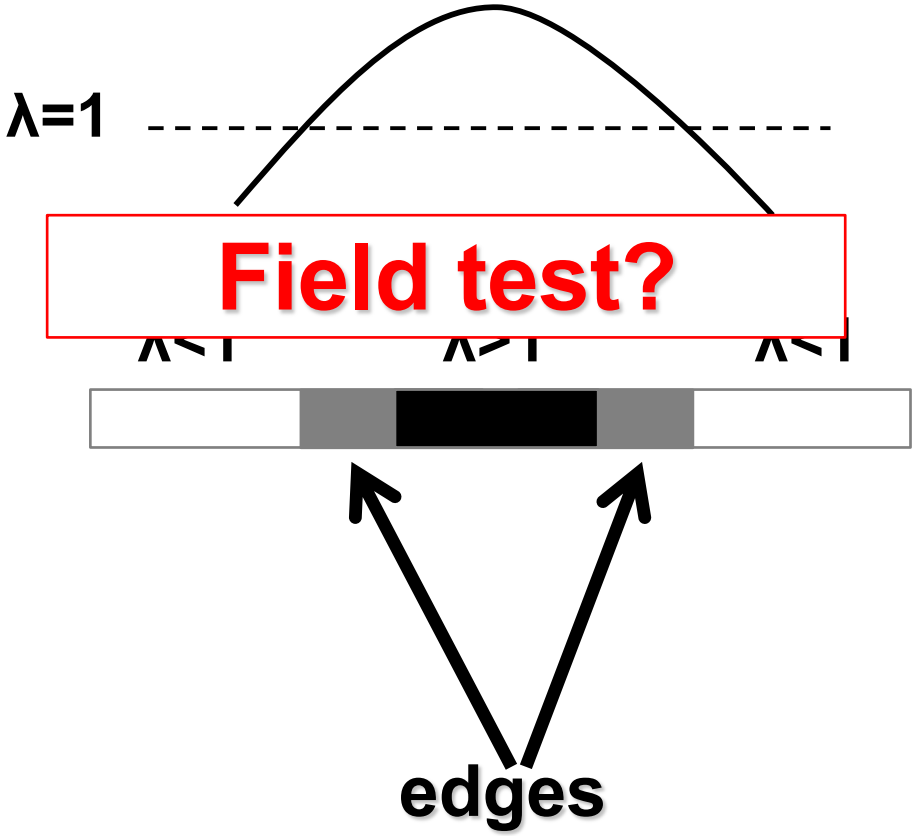
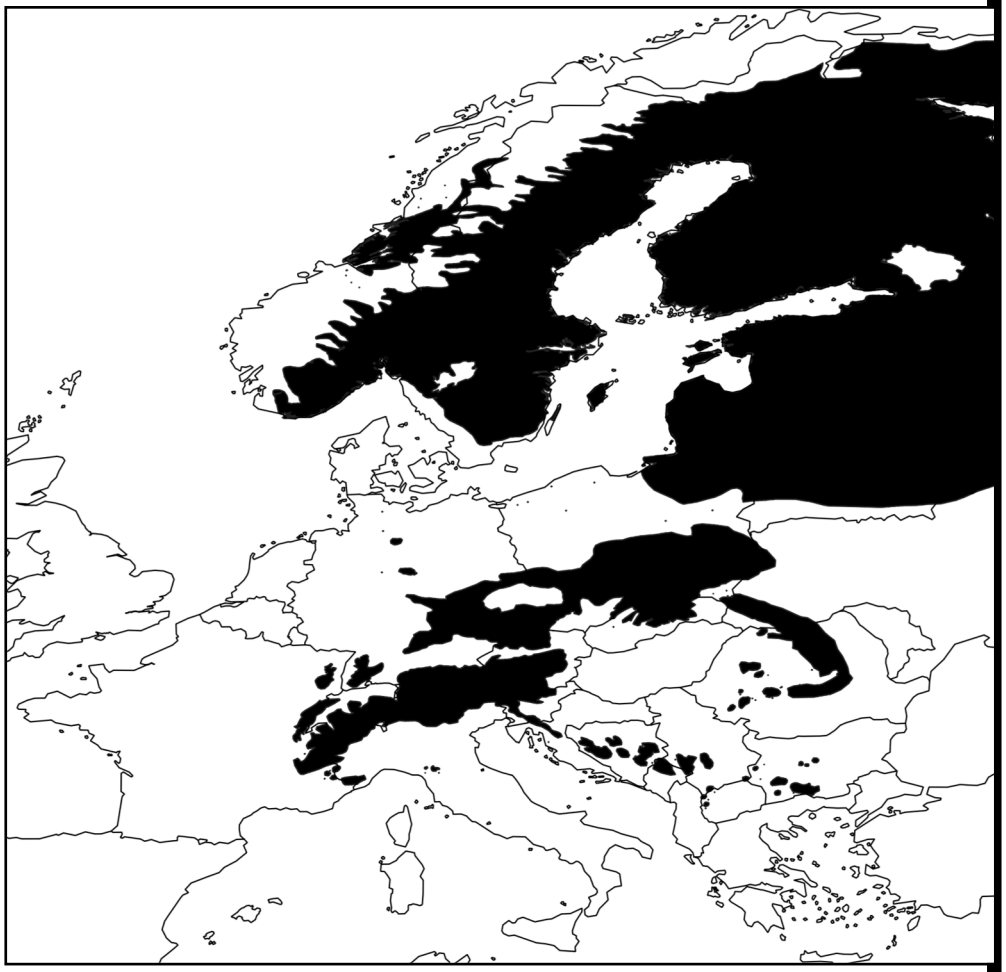


Species distribution and demography

Distribution

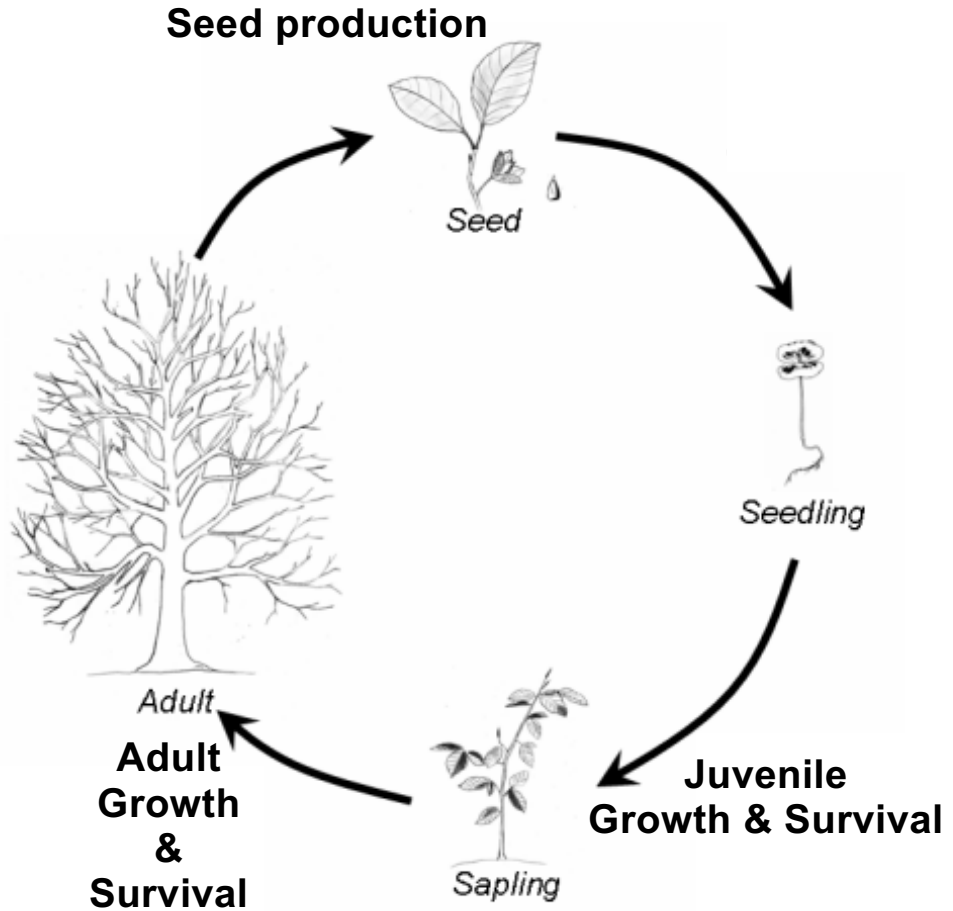


Picea abies

Trees=>

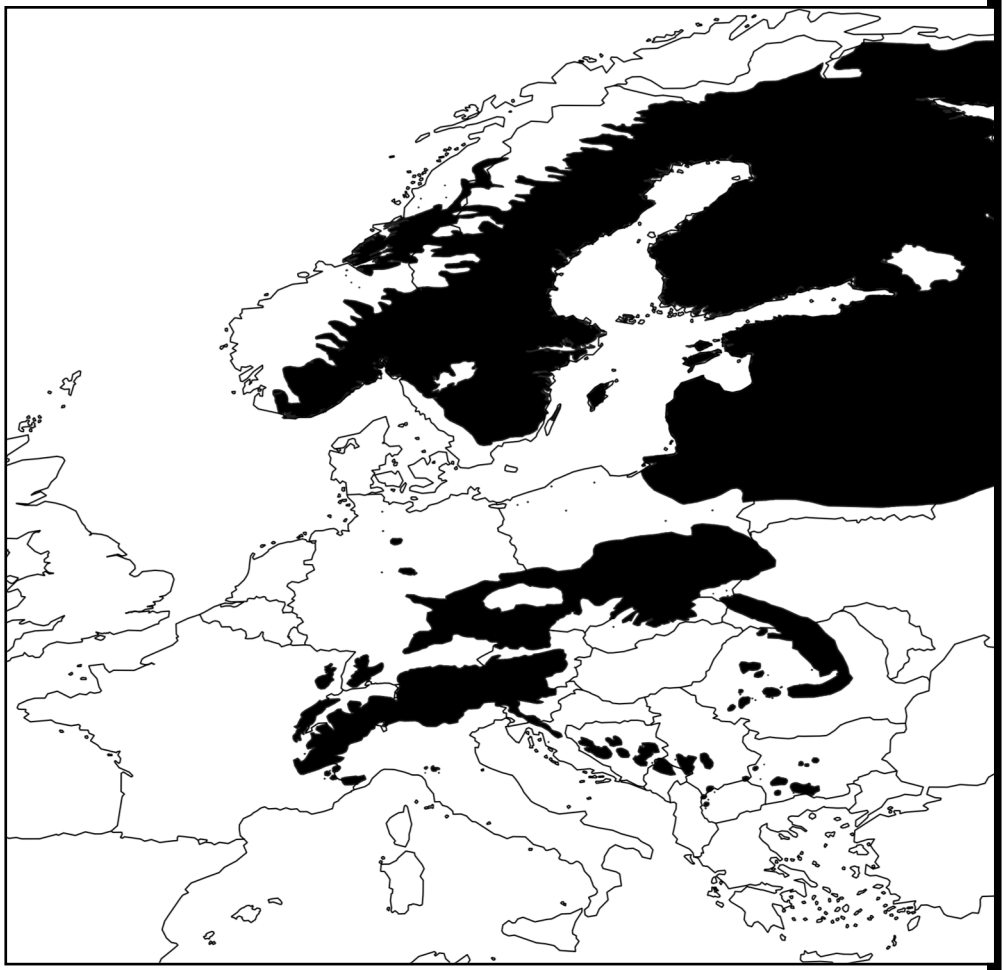
- long lived

- size structured demography



Species distribution and demography

Distribution



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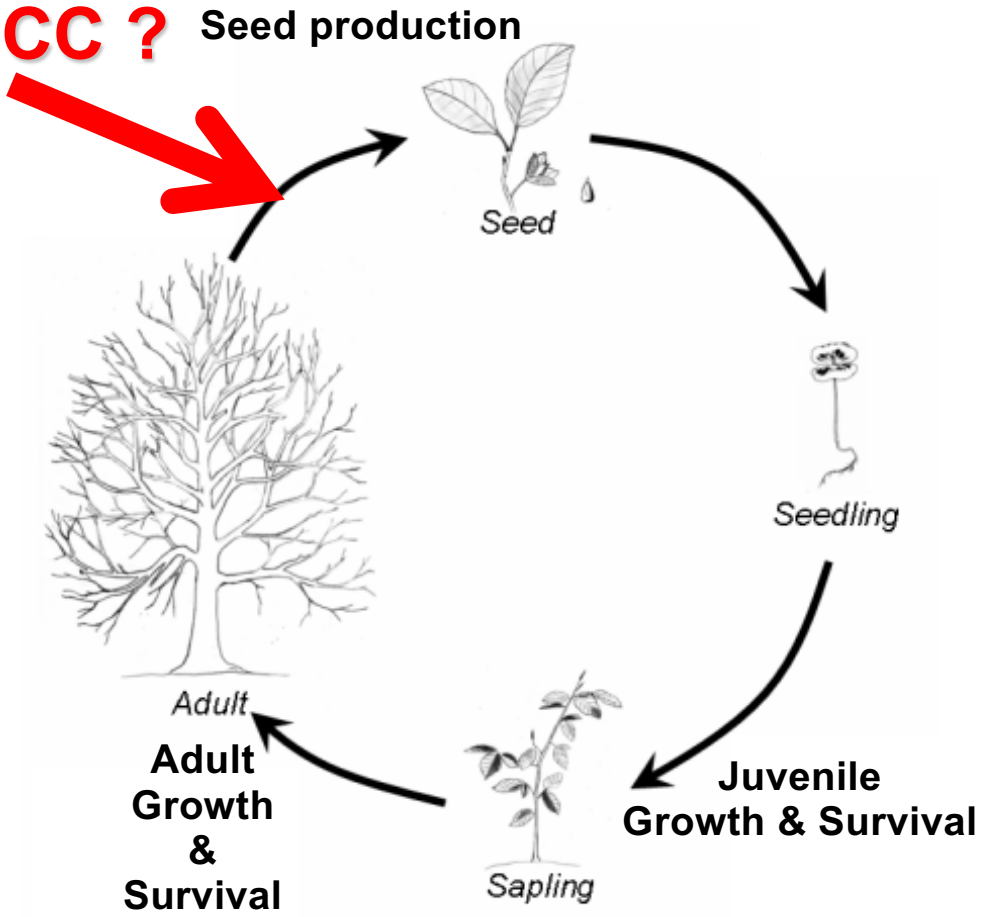
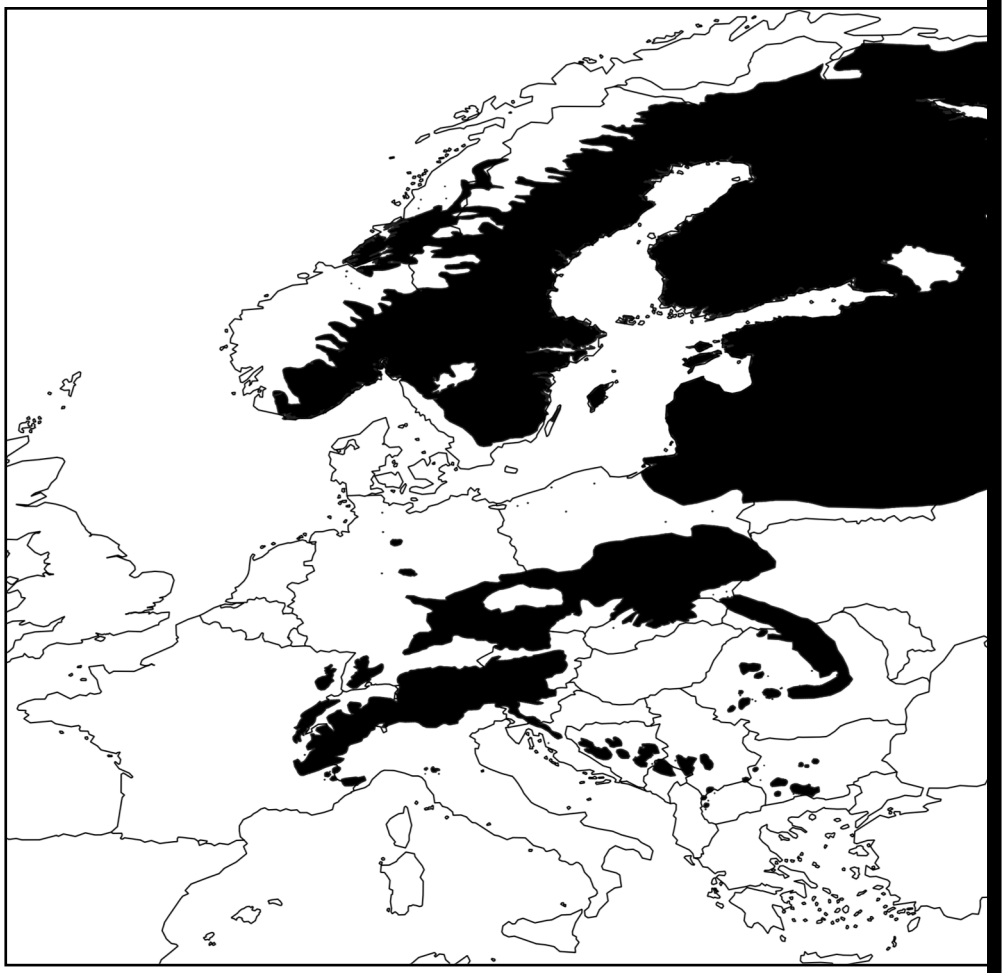


Species distribution and demography

Distribution



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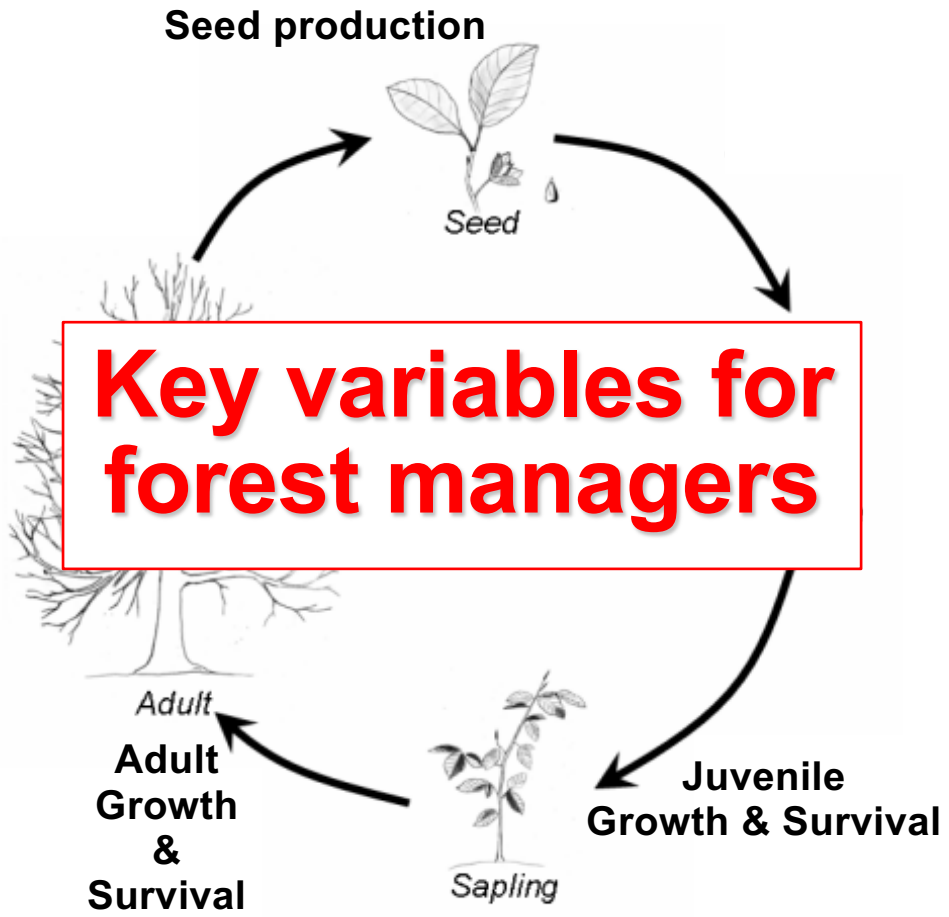
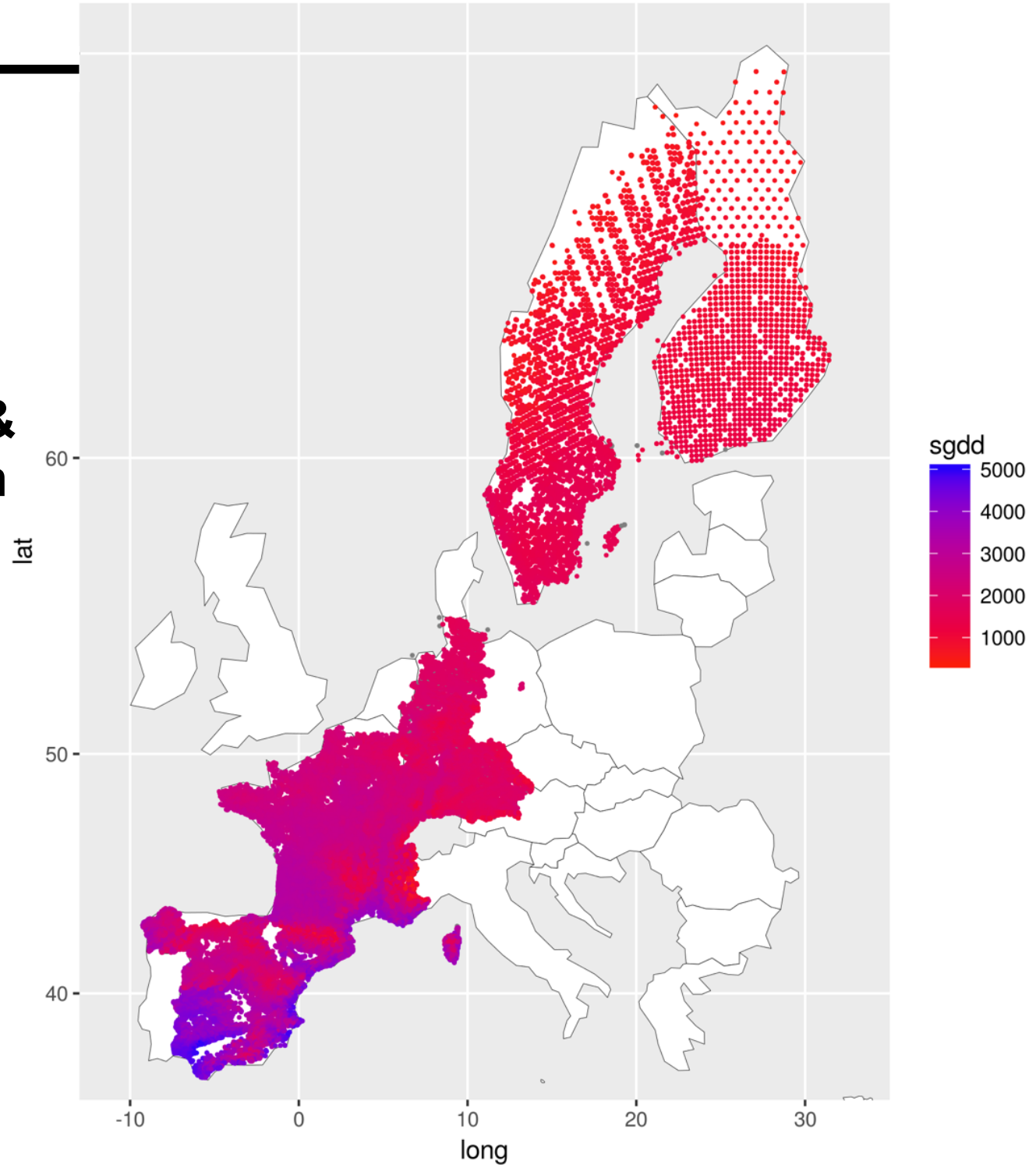


Approach & Hypothesis

- Forest inventories data

FUNDIV NFI data

- Forest inventories data across Europe (130 000 plots)
- Individual tree **growth, survival, & ingrowth** (>1million trees)
- 27 species



Approach & Hypothesis

- Forest inventories data

Hypothesis:

- **Vital rates and demographic performance drop at species edges**
- **Population equilibrium abundance and time to extinction drop at species edges**
- **Climate niche explains species demographic responses at the edges**

Statistical models

Growth, survival, and recruitment

⇒ Size & Competition (competitors basal area)

Climatic variables

⇒ Sum of growing degree days ***SGDD***

⇒ Water aridity index ***WAI***

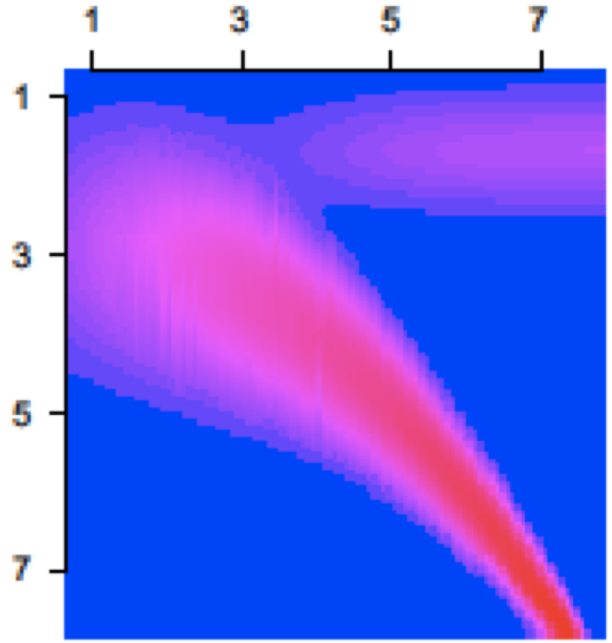
100 resamples of 70% of data & best models

- Asymptotic or polynomial responses

Combine Growth, Survival & Recruitment

=> Density-dependent Integral projection models IPM

Size at t x



= Size at t +1

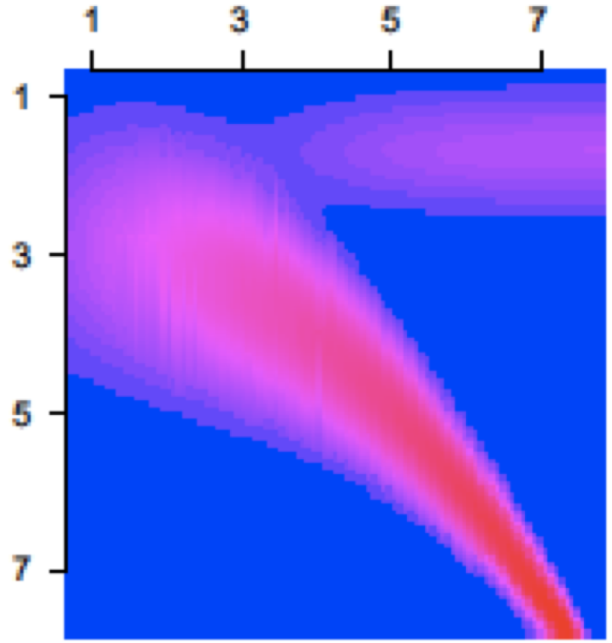
Combine Growth, Survival & Recruitment

=> Integral projection models density-dependent IPM

Life trajectories metrics

- Passage time
(from 10 to 60 cm)
- Lifespan

Size at t **x**



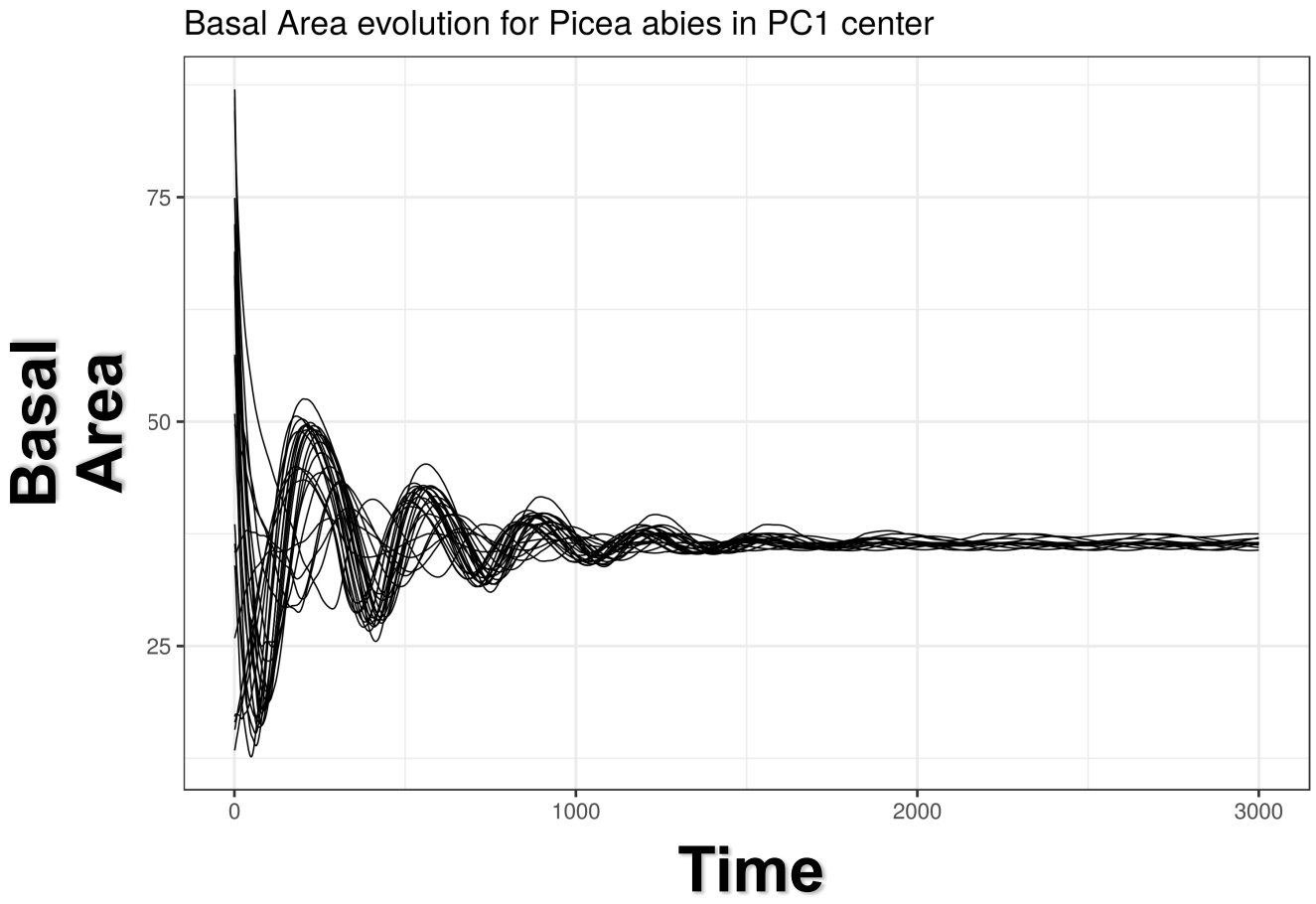
= Size at t +1

Combine Growth, Survival & Recruitment

=> Integral projection models density-dependent IPM

Life trajectories metrics
- Passage time
- Lifespan

Equilibrium
- Basal area

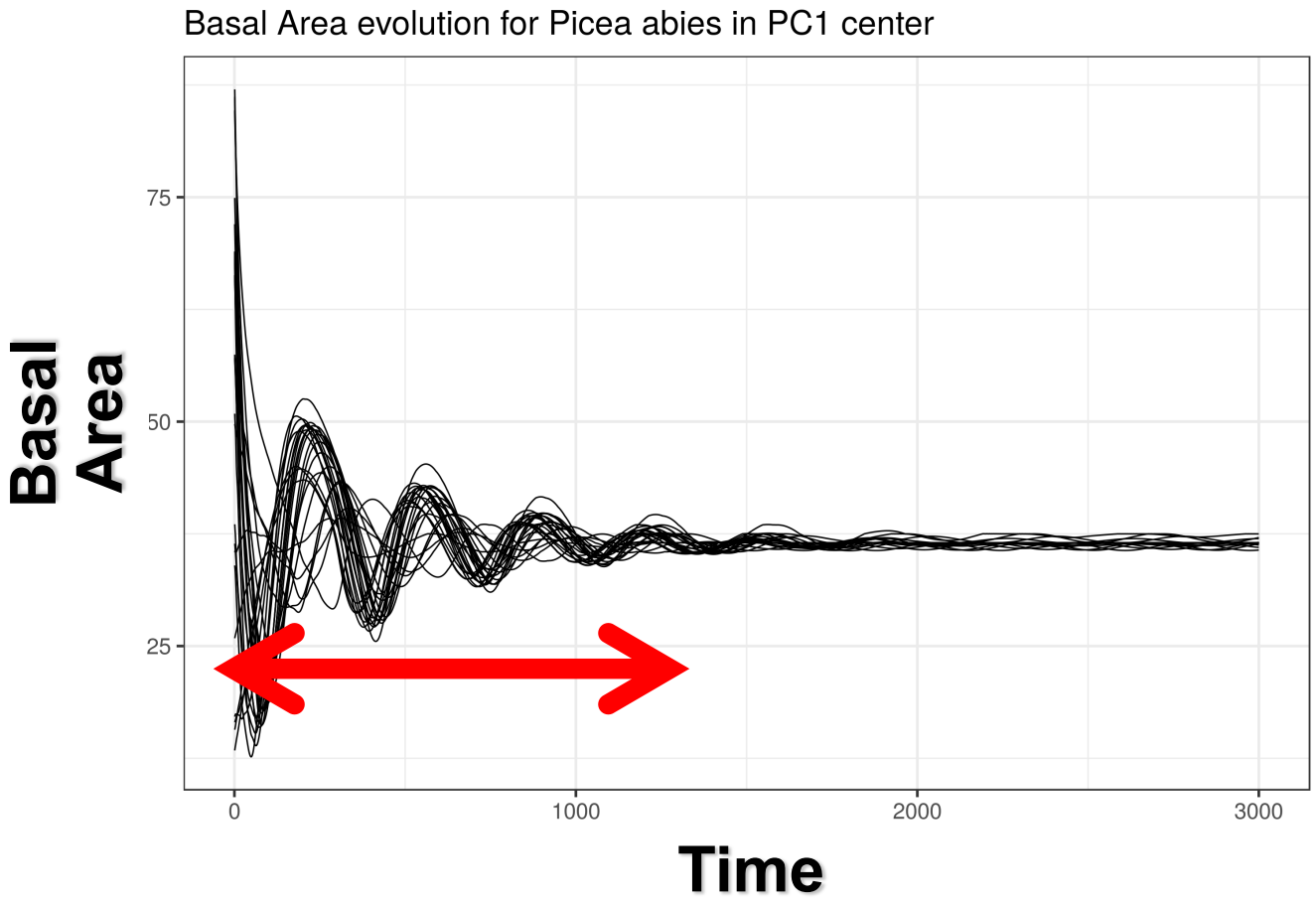


Combine Growth, Survival & Recruitment

=> Integral projection models density-dependent IPM

Life trajectories metrics
- Passage time
- Lifespan

Equilibrium
- Basal area
- Damping time



Combine Growth, Survival & Recruitment

=> Integral projection models density-dependent IPM

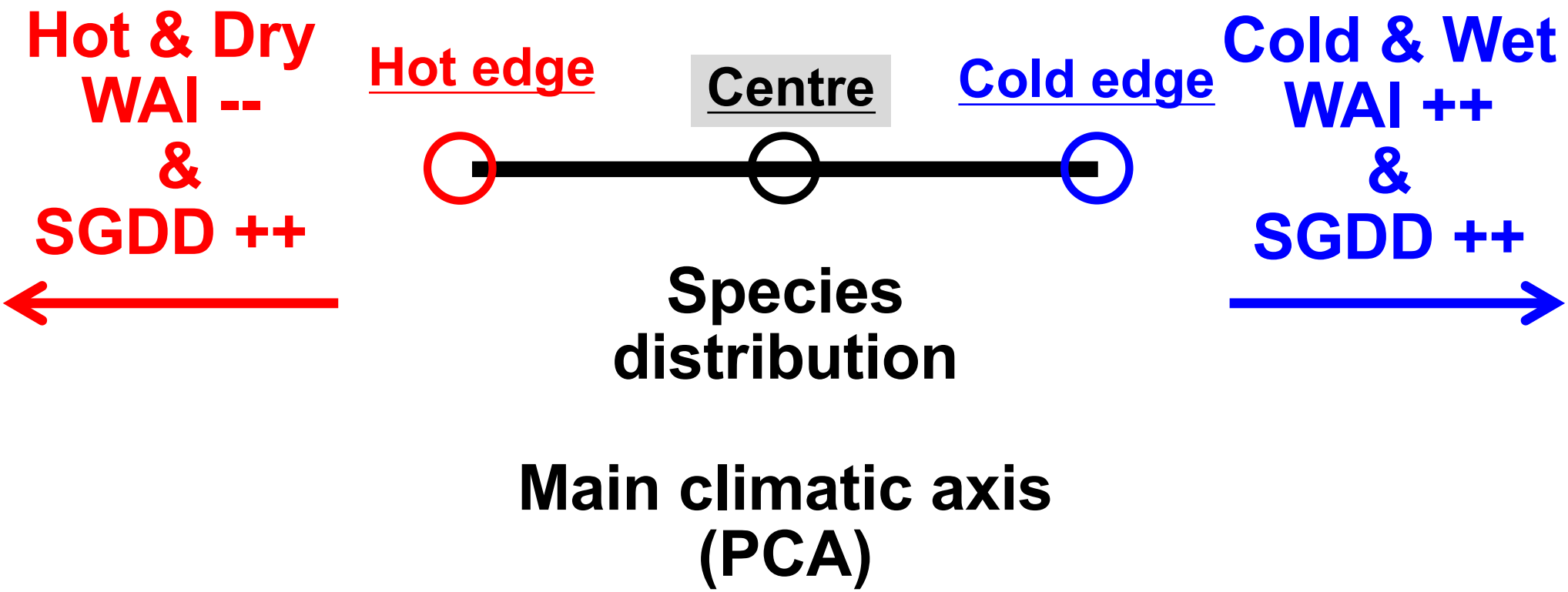
Life trajectories metrics

- Passage time
- Lifespan

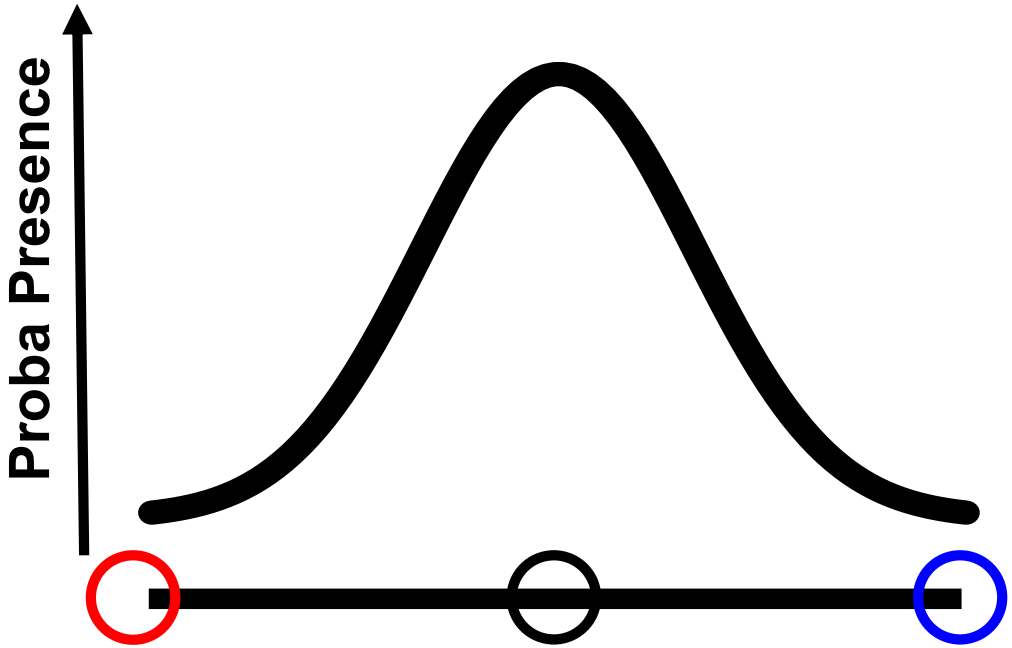
Equilibrium

- Basal area
- Damping time
- Time to extinction (small populations 0.1 ha)

Select edges along a single axis

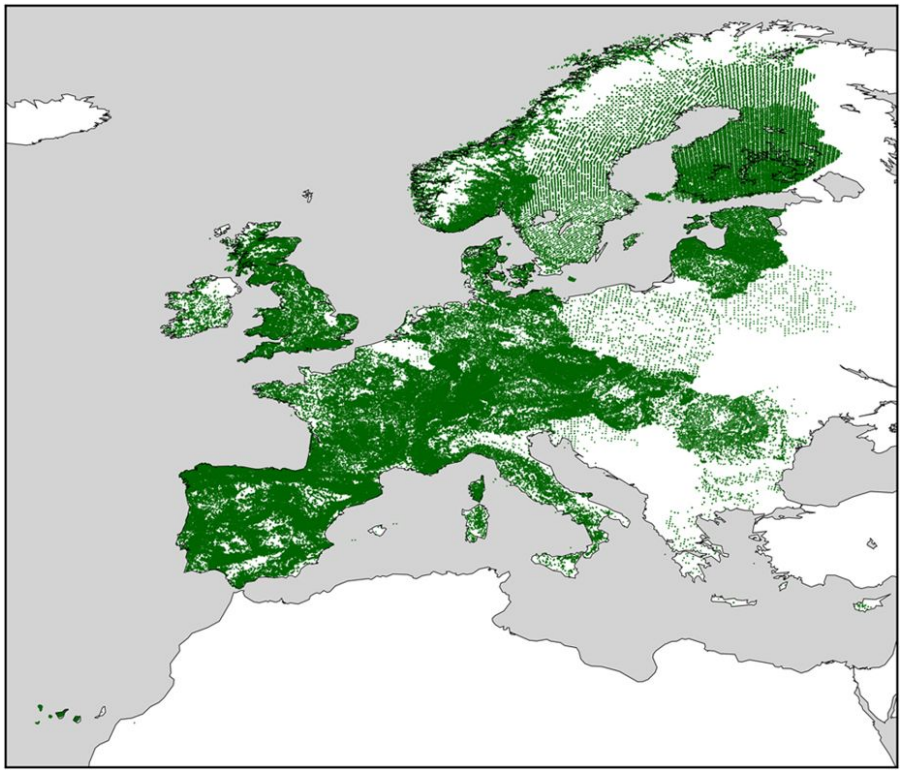


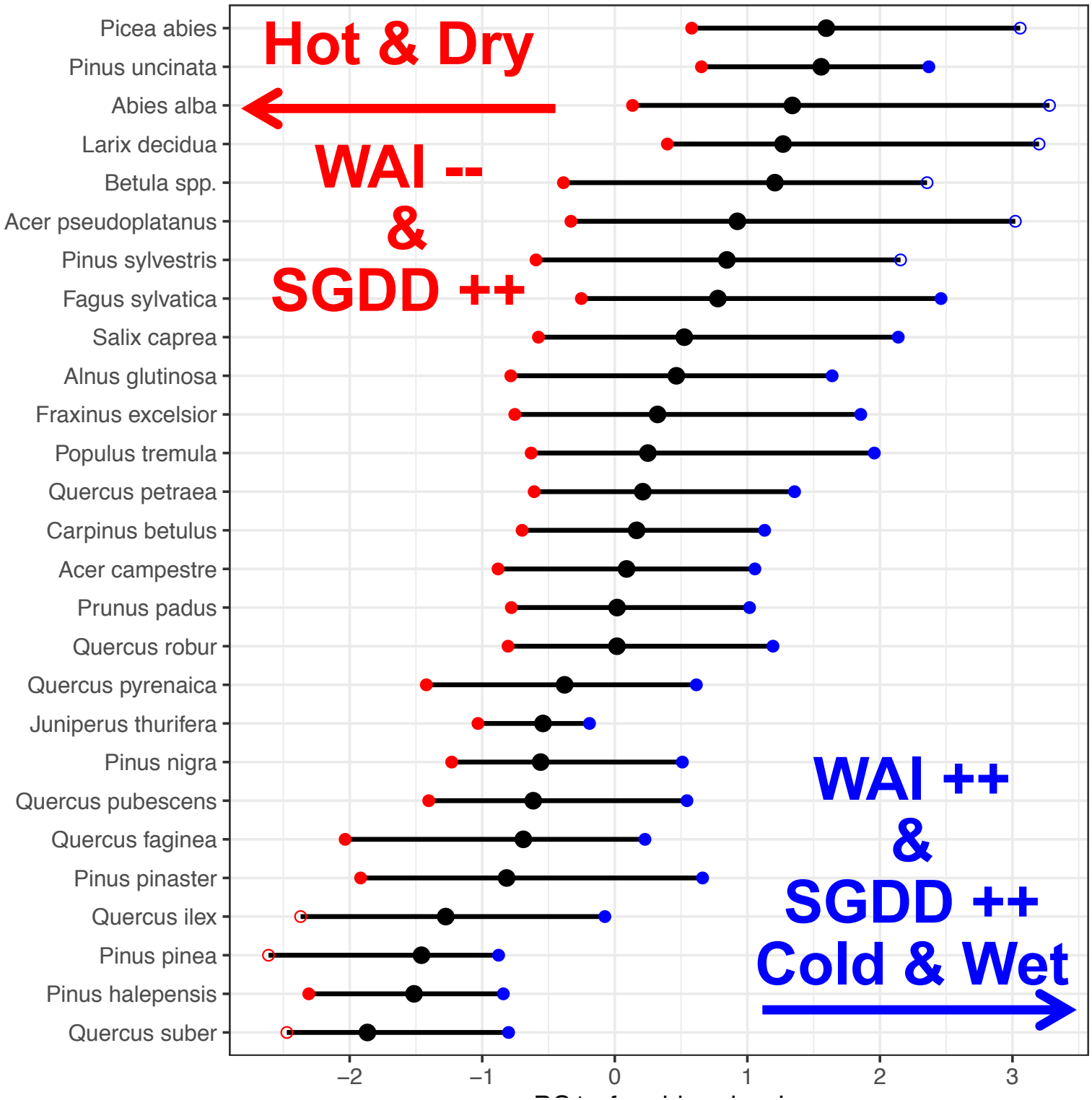
Select edges with decrease proba of presence



Ensemble SDM models with BIOMOD2

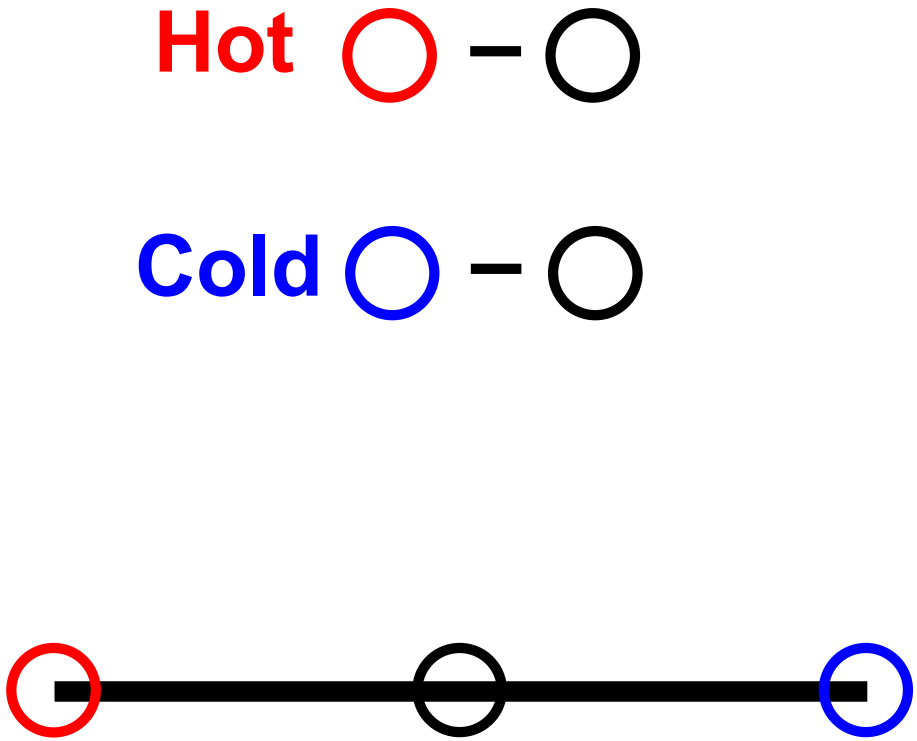
EU-Forest

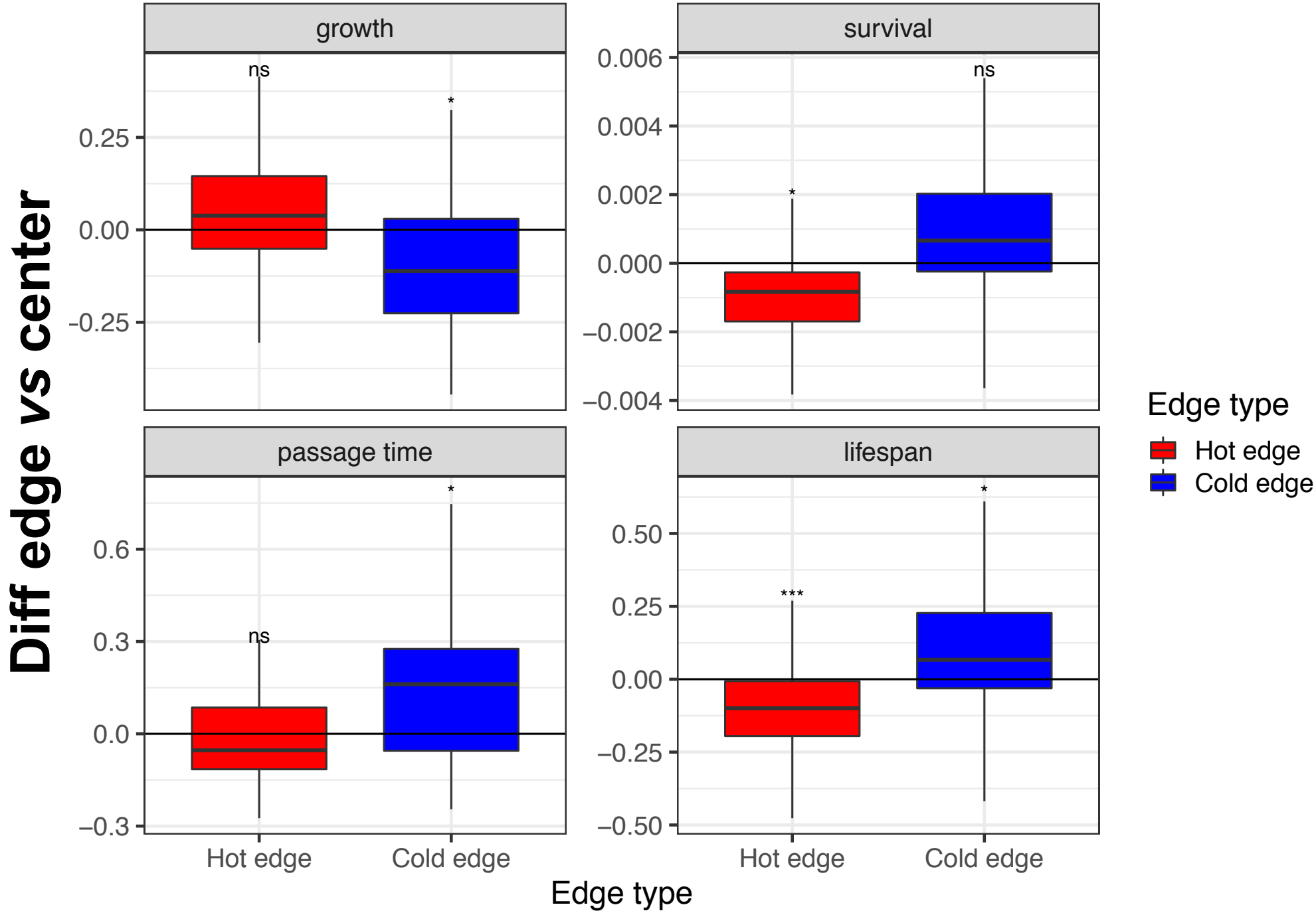


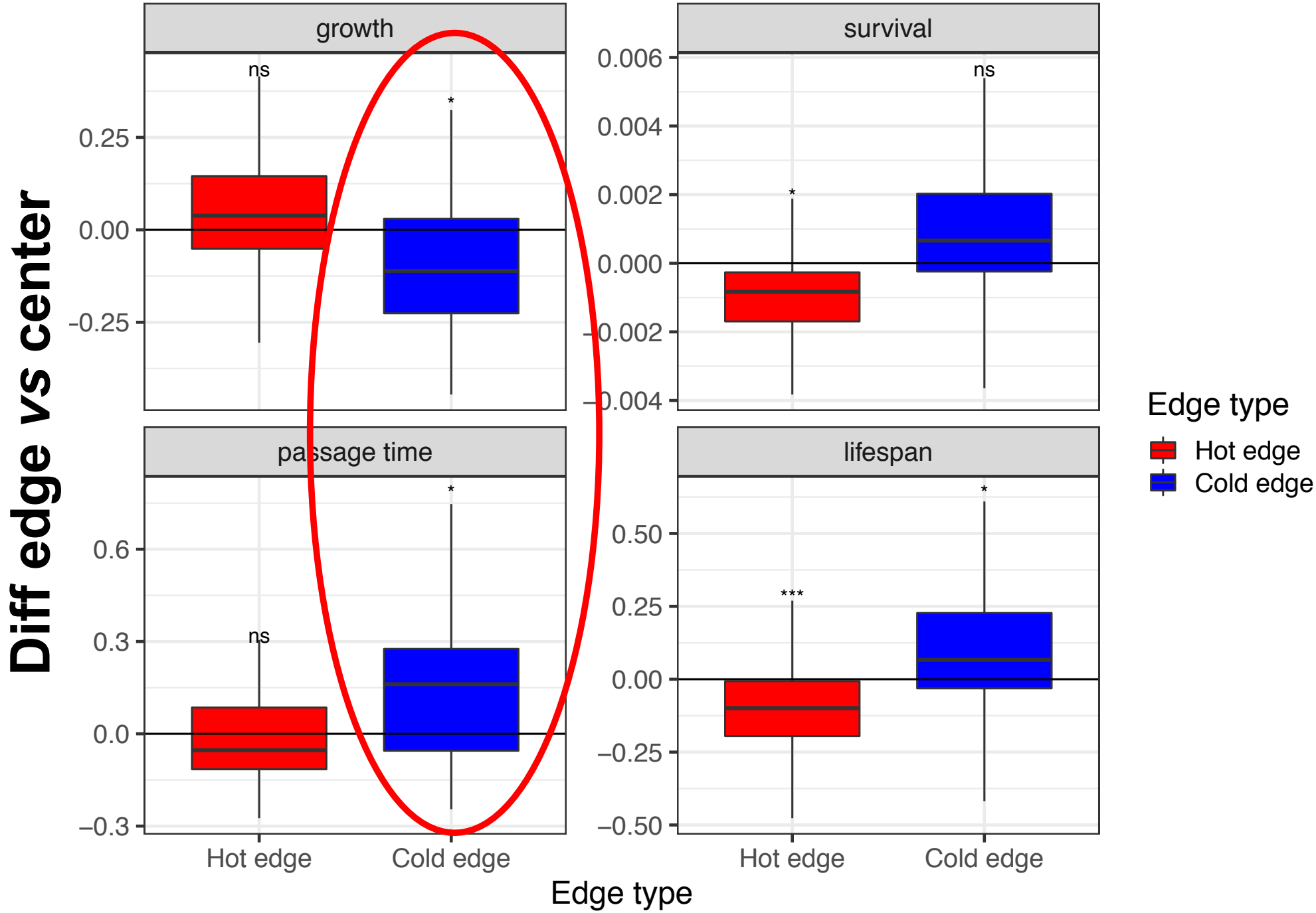

Hot & Dry
WAI --
&
SGDD ++
WAI ++
&
SGDD ++
Cold & Wet
Picea abies
Pinus uncinata
Abies alba
Larix decidua
Betula spp.
Acer pseudoplatanus
Pinus sylvestris
Fagus sylvatica
Salix caprea
Alnus glutinosa
Fraxinus excelsior
Populus tremula
Quercus petraea
Carpinus betulus
Acer campestre
Prunus padus
Quercus robur
Quercus pyrenaica
Juniperus thurifera
Pinus nigra
Quercus pubescens
Quercus faginea
Pinus pinaster
Quercus ilex
Pinus pinea
Pinus halepensis
Quercus suber
−2
−1
0
1
2
3

Differences in demographic rate edge *vs* center

Diff center *vs* edge




growth
survival
passage time
lifespan
ns
*
ns
*
ns
*
***
*
0.25
0.00
-0.25
0.006
0.004
0.002
0.000
−0.002
−0.004
0.6
0.3
0.0
−0.3
0.50
0.25
0.00
−0.25
−0.50
Hot edge
Cold edge
Edge type
Diff edge vs center
Edge type
Hot edge
Cold edge


Diff edge vs center
growth
survival
passage time
lifespan
ns
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ns
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ns
*
***
*
0.25
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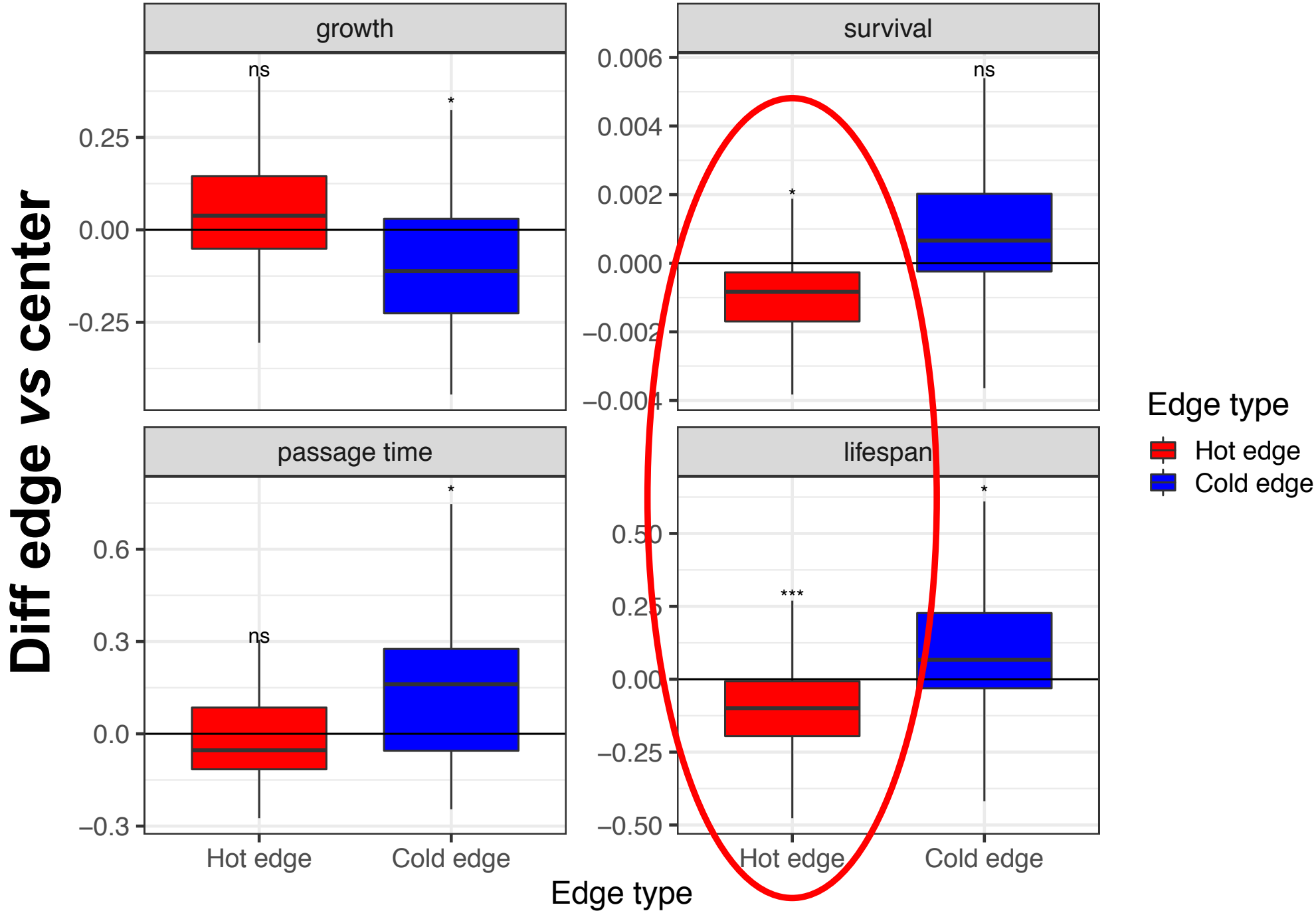
-0.25
0.006
0.004
0.002
0.000
−0.002
−0.004
0.6
0.3
0.0
−0.3
0.50
0.25
0.00
−0.25
−0.50
Hot edge
Cold edge
Edge type
Edge type
Hot edge
Cold edge


growth
survival
passage time
lifespan
ns
*
ns
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ns
*
***
*
0.25
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-0.25
0.006
0.004
0.002
0.000
−0.002
−0.004
0.6
0.3
0.0
−0.3
0.50
0.25
0.00
−0.25
−0.50
Hot edge
Cold edge
Hot edge
Cold edge
Edge type
Diff edge vs center
Edge type
Hot edge
Cold edge

No general drop of demographic rates

- Growth and passage time decrease at the cold edge
- Survival and lifespan decrease at hot edge

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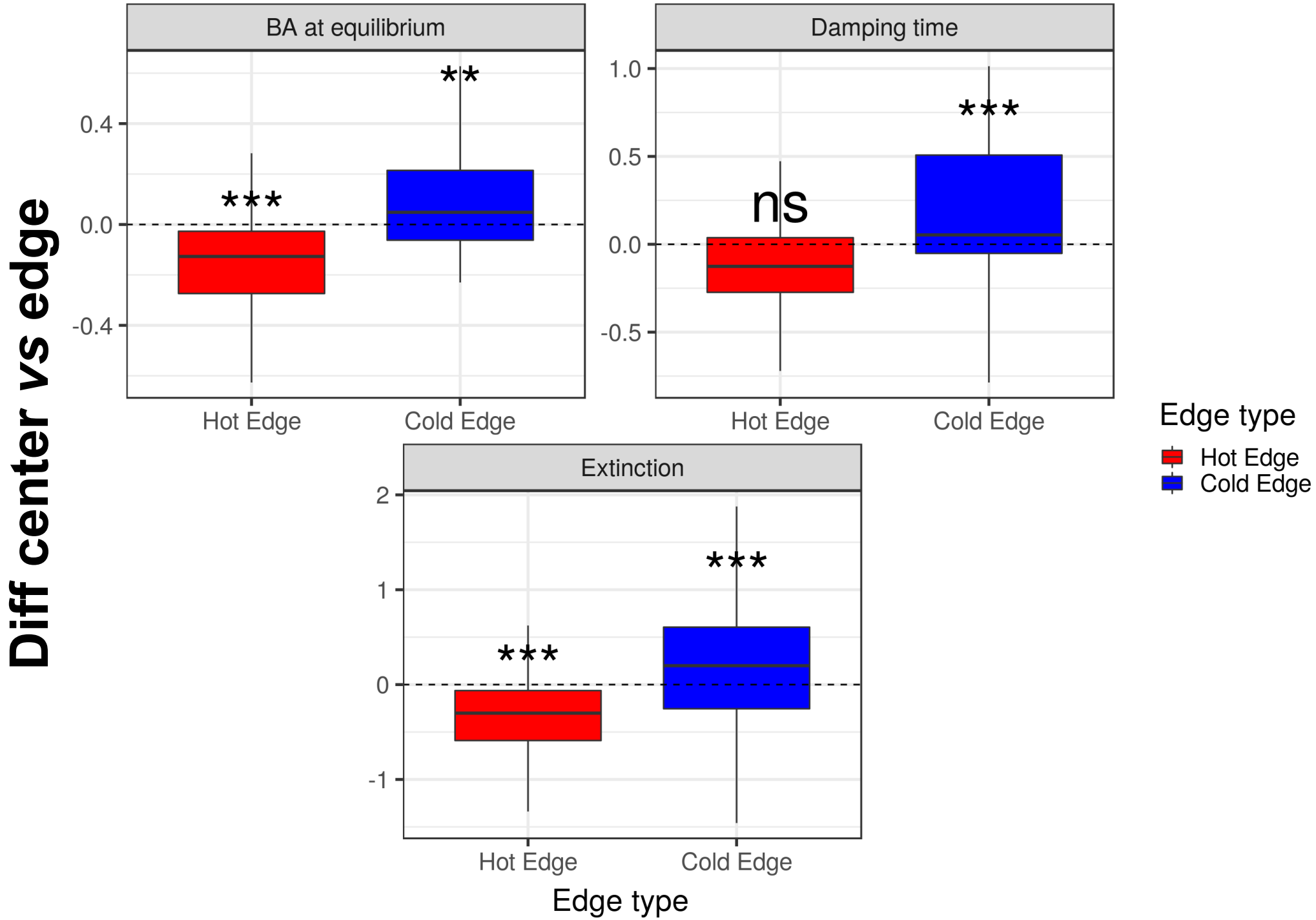
Long term population dynamics?


BA at equilibrium
Damping time
Extinction
Diff center vs edge
Edge type
Hot Edge
Cold Edge
0.4
0.0
-0.4
1.0
0.5
-0.5
2
1
0
-1
**
***
ns

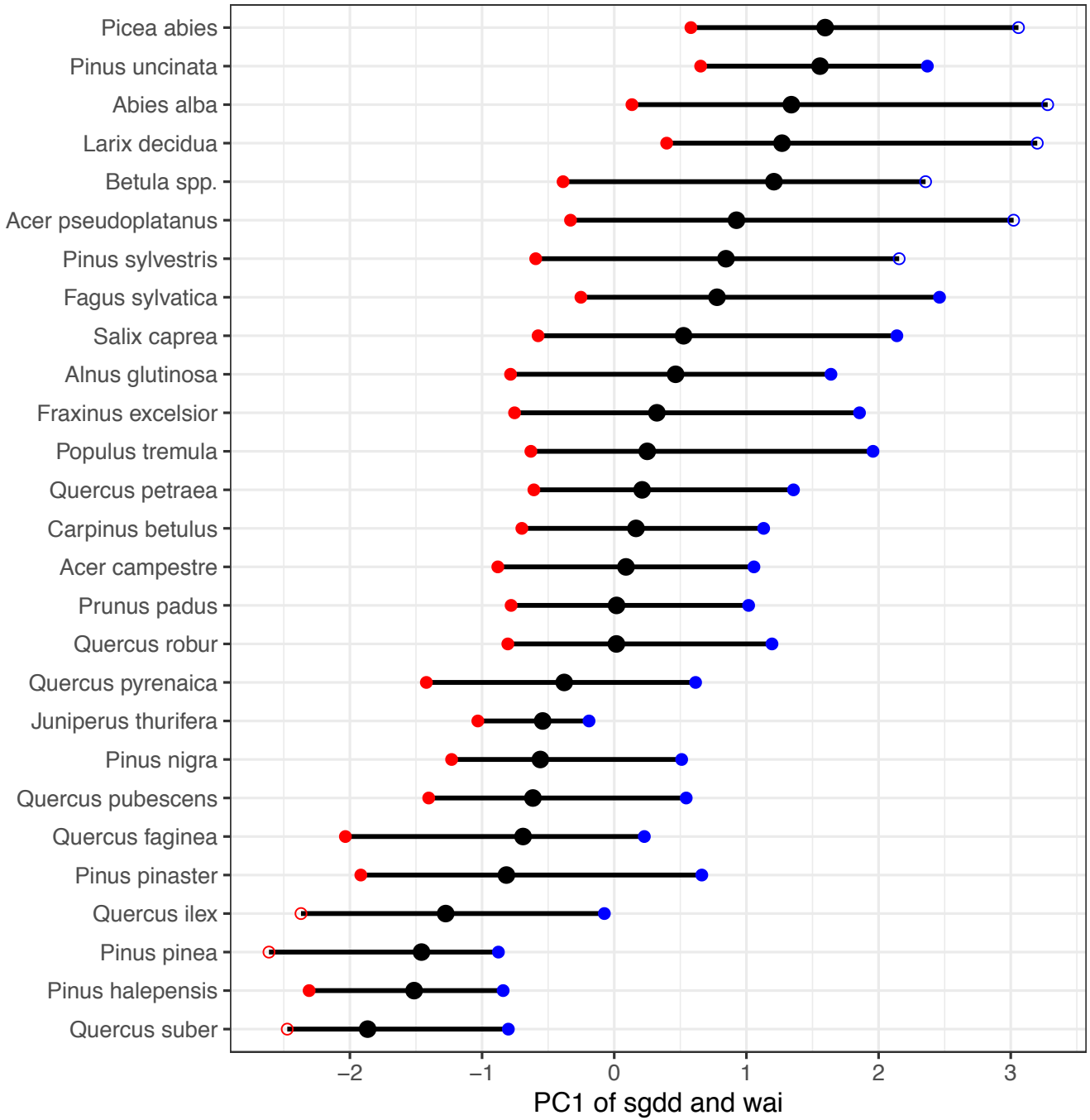
No general drop of demographic rates

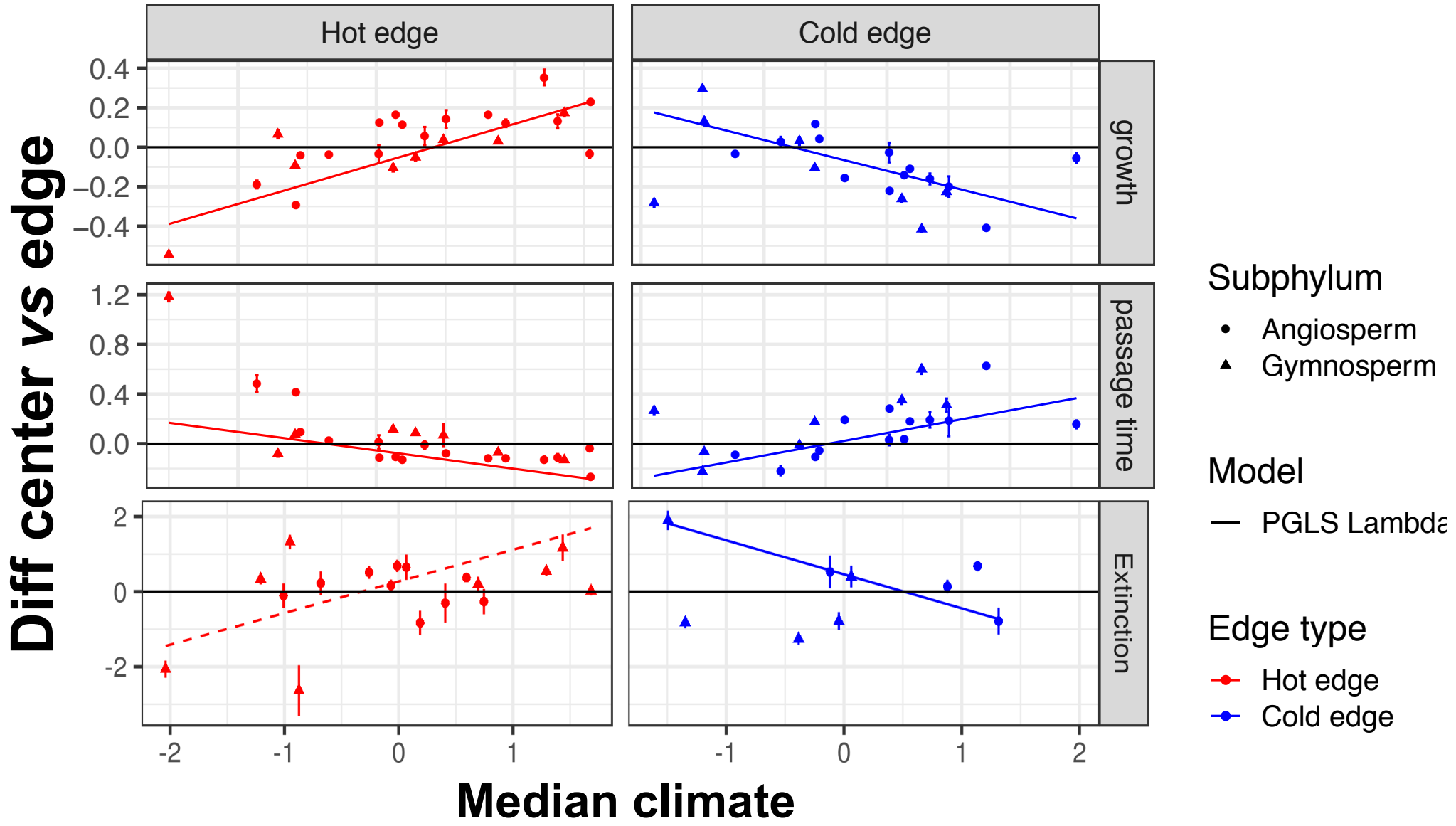
- Growth and passage time decrease at the cold edge
- Survival and lifespan decrease at hot edge
- Recruitment => no effect

Long term population dynamics?

- Basal area at equilibrium and time to extinction decrease at hot edge but increase at cold edge
- Slower damping at cold edge

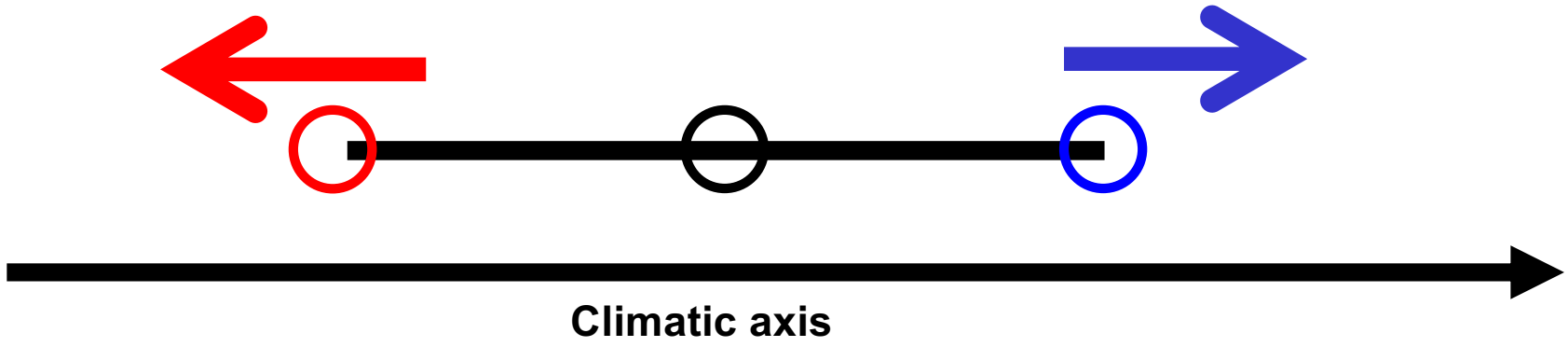
How species climatic optimum drives the responses?




Hot edge
Cold edge
growth
passage time
Extinction
Diff center vs edge
Median climate
0.4
0.2
0.0
−0.2
−0.4
1.2
0.8
0.4
0.0
2
0
-2
-2
-1
0
1
-1
0
1
2
Subphylum
Angiosperm
Gymnosperm
Model
PGLS Lambda
Edge type
Hot edge
Cold edge

How climate optimum drive species responses?

⇒ **Stronger decrease in performance for species with edge in more extreme climate**



Conclusion

Conclusion

► **General patterns**

- higher mortality and extinction at hot edge
- slower growth and damping at cold edge

→ **Stronger demographic limitations for edges in extreme climate**

Conclusion

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► **Not all species have lower demographic performance or population dynamics at their edge**

Conclusion

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► **Not all species have lower demographic performance or population dynamics at their edge**

SDM ⟶ **Population performance**

Conclusion

► **General patterns**

- higher mortality and extinction at hot edge
- slower growth and damping at cold edge

→ **Stronger demographic limitations for edges in extreme climate**

► **Not all species have lower demographic performance or population dynamics at their edge**

→ **Climate change negative impact not necessarily at the edge!**

Recent dieback events not necessarily observed at the edge

Thank you

Guyennon A., Reineking, B., Childs D. Z., Dahlgren J., Kändler, G., Lehtonen, A., Ratcliffe, S., Ruger, N., Ruiz-Benito, P., Salguero-Gomez, R., Thuiller, W., Wirth, C., Zavala, M. A., and sAPROPOS group sDIV