Climate adaptation and diversity in interior conifers

Sally Aitken, UBC

January (2022 - really?)

Traditional territory of the Kwakwaka'kwaka and Wei Wai Kai

Project Overview

End user needs

Trees adapted to new climates

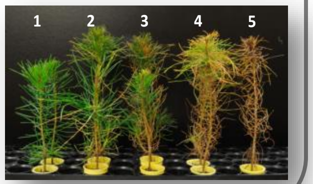
Trees adapted to increased disease pressure

Policies and practices acceptable to public and stakeholders

Trees, pathogens and climates

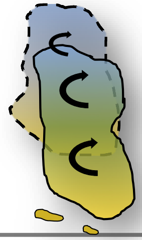
Activity 1: Climate adaptation of 4 tree species

Activity 2: Disease resistance of 2 tree species



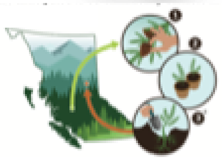
Activity 3: Pathogenic races of fungi

Activity 4: Assisted migration & breeding strategies



Society

Activity 5: Levels and logics of support for emerging adaptation options across governments, stakeholders, and the public

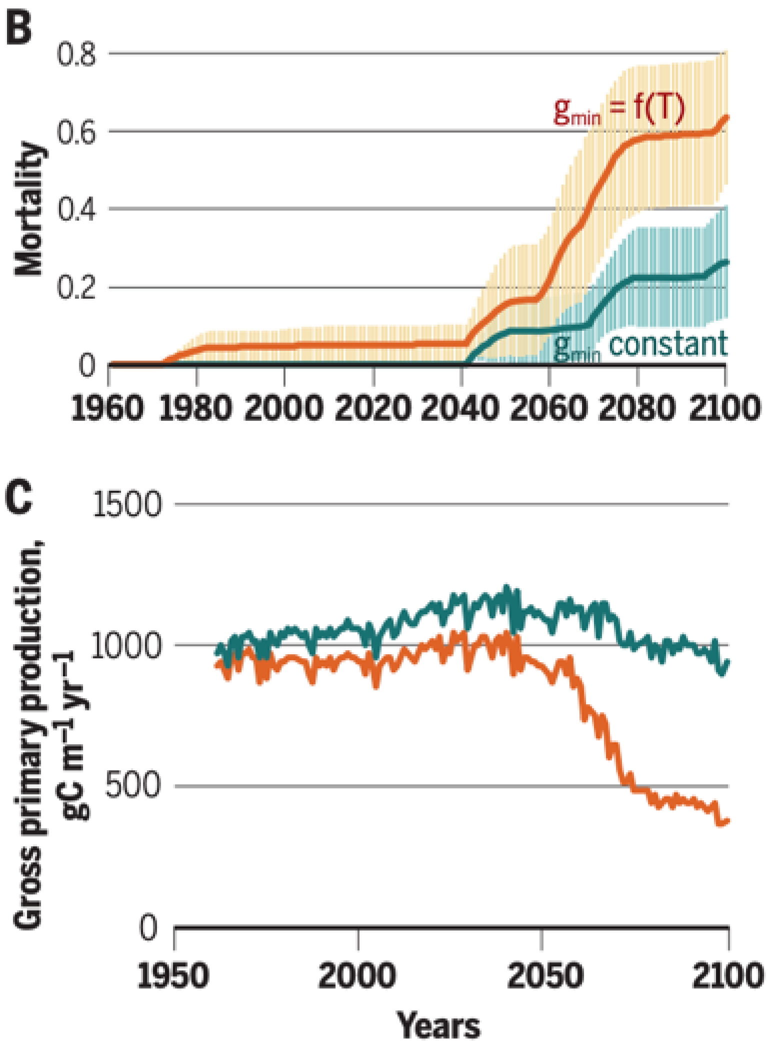


Deliverables

1) Policy and reforestation recommendations
2) Genomic tools and strategies
3) Translational strategies tailored to specific forestry contexts

Local adaptation of tree populations has primarily been driven by cold temperatures


Drought may be becoming one of the main agents of selection (& mortality)

Brodribb et al. Science (2020)

CoAdapTree
Healthy Trees for Future Climates

Increasing evidence of drought injury and mortality at different tree ages

With climate-based seed transfer, need to consider risks of cold injury

Contents lists available at ScienceDirect

Climate Risk Management

journal homepage: www.elsevier.com/locate/crm

Assisted migration poleward rather than upward in elevation minimizes frost risks in plantations

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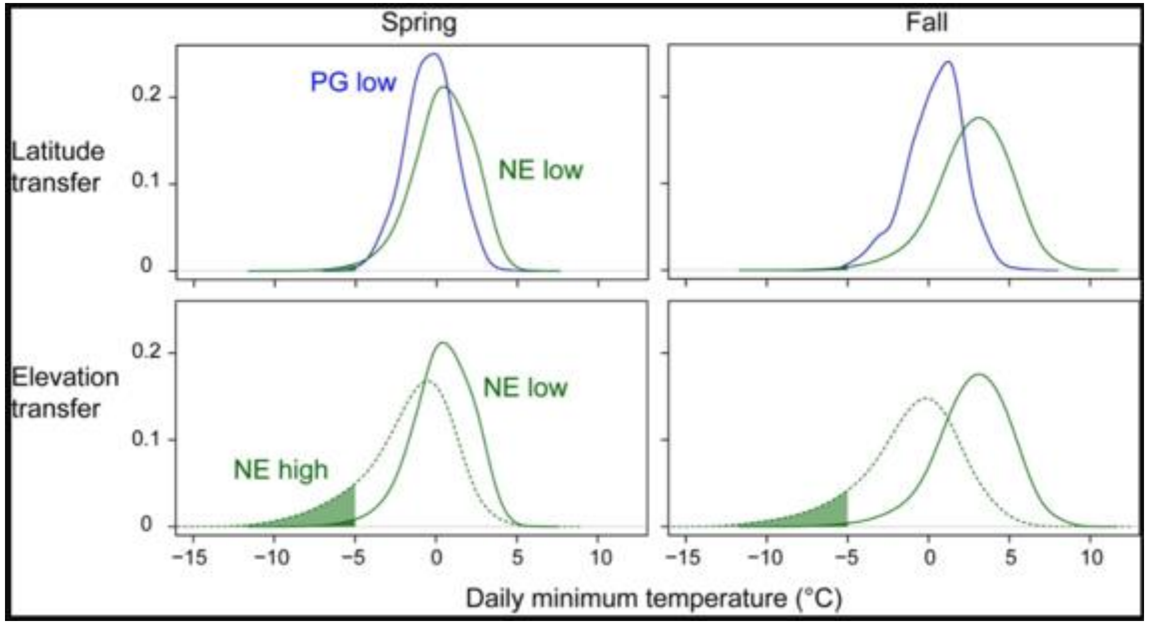


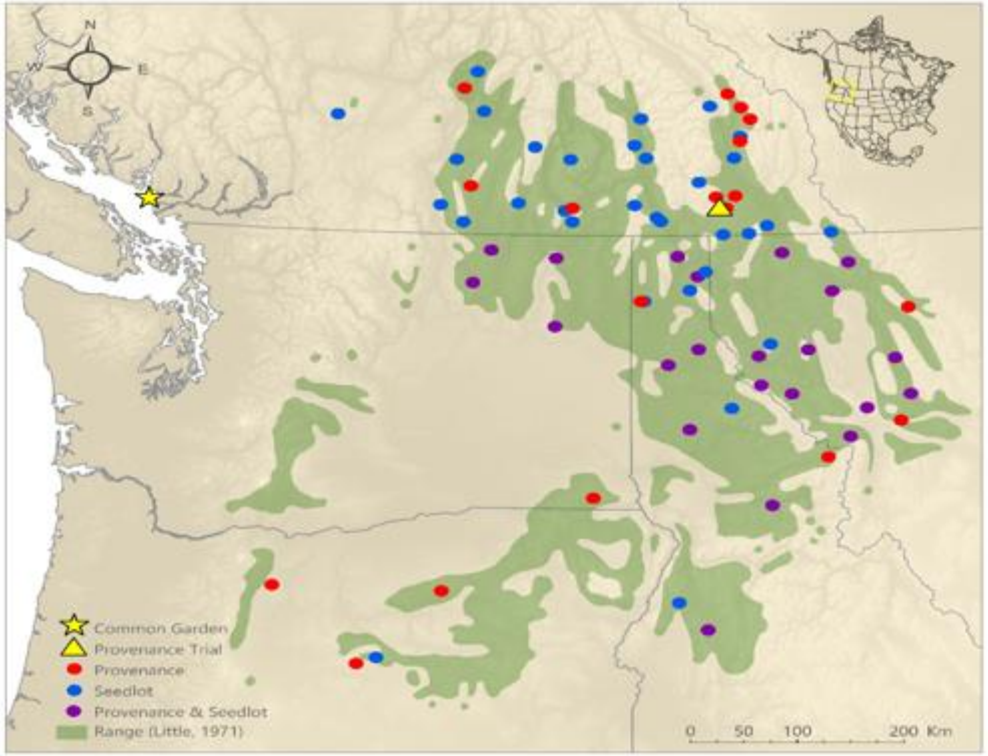
Transfers north change risks of frost injury very little; transfers up in elevation increase risk of late spring frosts from 0.5 to 9.4% and fall frosts from 0.5 to 17%

Outline

- Climate adaptation and drought response of seedlings
  - Western larch
  - Douglas-fir
- Using genomic data to project maladaptation with climate change
- Landscape Genetic Diversity Project
  - Lodgepole pine
  - Interior spruce
  - Douglas-fir

Western larch climate adaptation and drought tolerance

Beth Roskilly, PhD candidate



- 52 natural populations in common gardens
- 40 natural populations from provenance trial
- 32 populations overlap in common gardens & provenance trial
- 28 families from breeding programs

CoAdapTree
Healthy Trees for Future Climates

Research questions

1) How much do populations vary for climate-related traits?

- growth
- bud phenology
- fall cold hardiness
- drought tolerance

2) How does selective breeding affect climate adaptation?

Larch drought experiment 2021

- 3 treatments:

  control, drought, and recovery
- drought covers were up by May 18th, 2021
- control treatment was regularly watered to maintain high soil VWC
- drought treatment was not watered until Oct 14th (5 months)
- recovery treatment was rewatered on Aug 13th (after 3 months)

Measurements

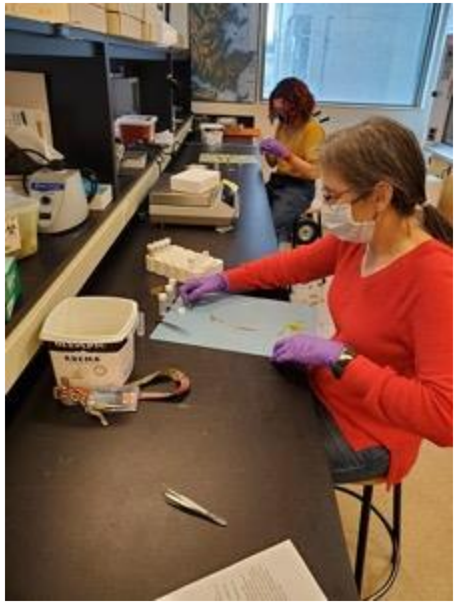
heights
<u>6x 2880</u>
17,280

bud break
<u>7x 2880</u>
20,160

bud set
<u>15x 2880</u>
43,200

water potentials
<u>7x 36</u>
252

fluorescence
<u>8x 1920</u>
15,360



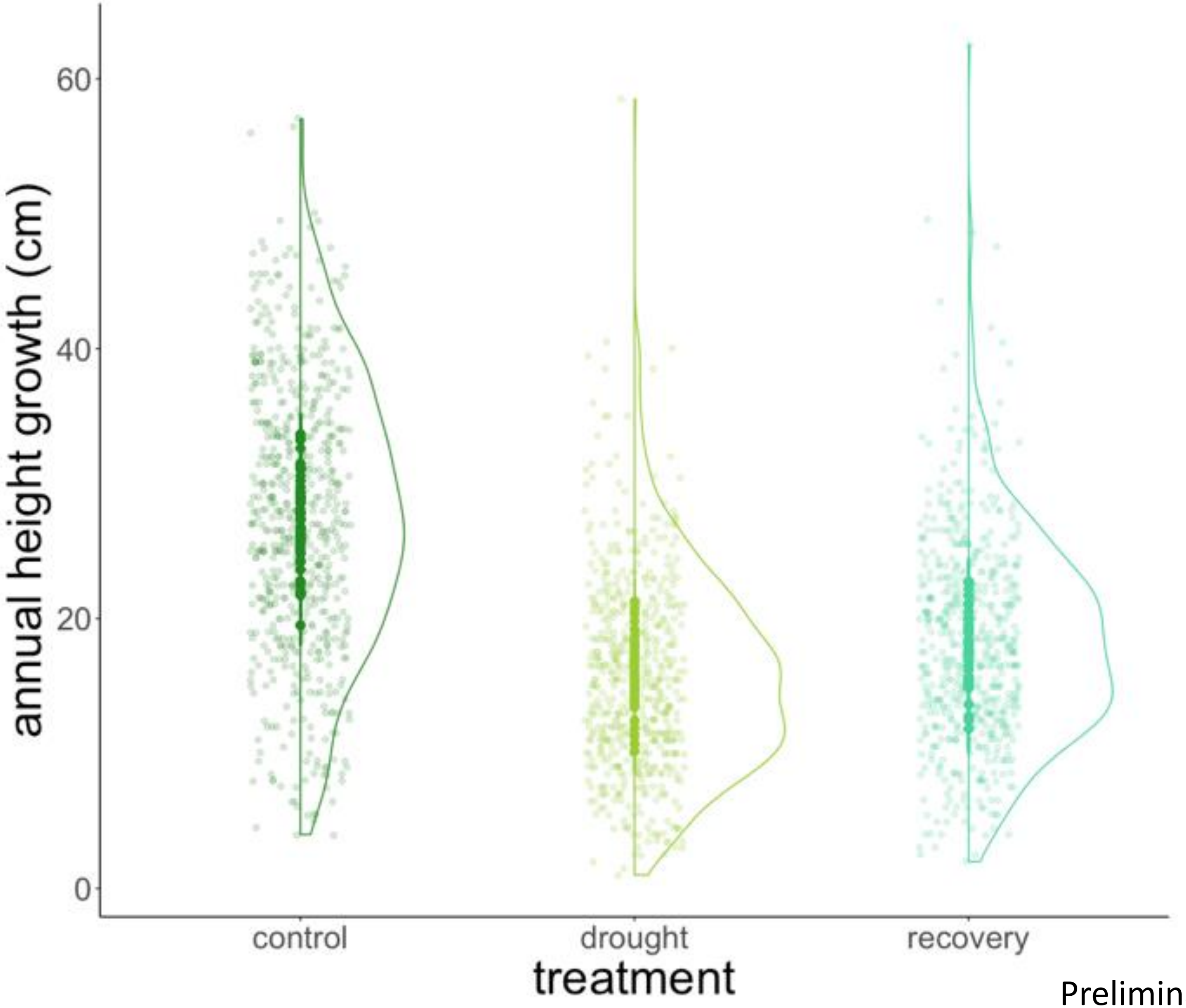
cold injury
<u>2x 1100</u>
2,200

Leaf senescence

Nov 2, 2020

Nov 11, 2020

Annual height growth significantly reduced by drought and recovery treatment



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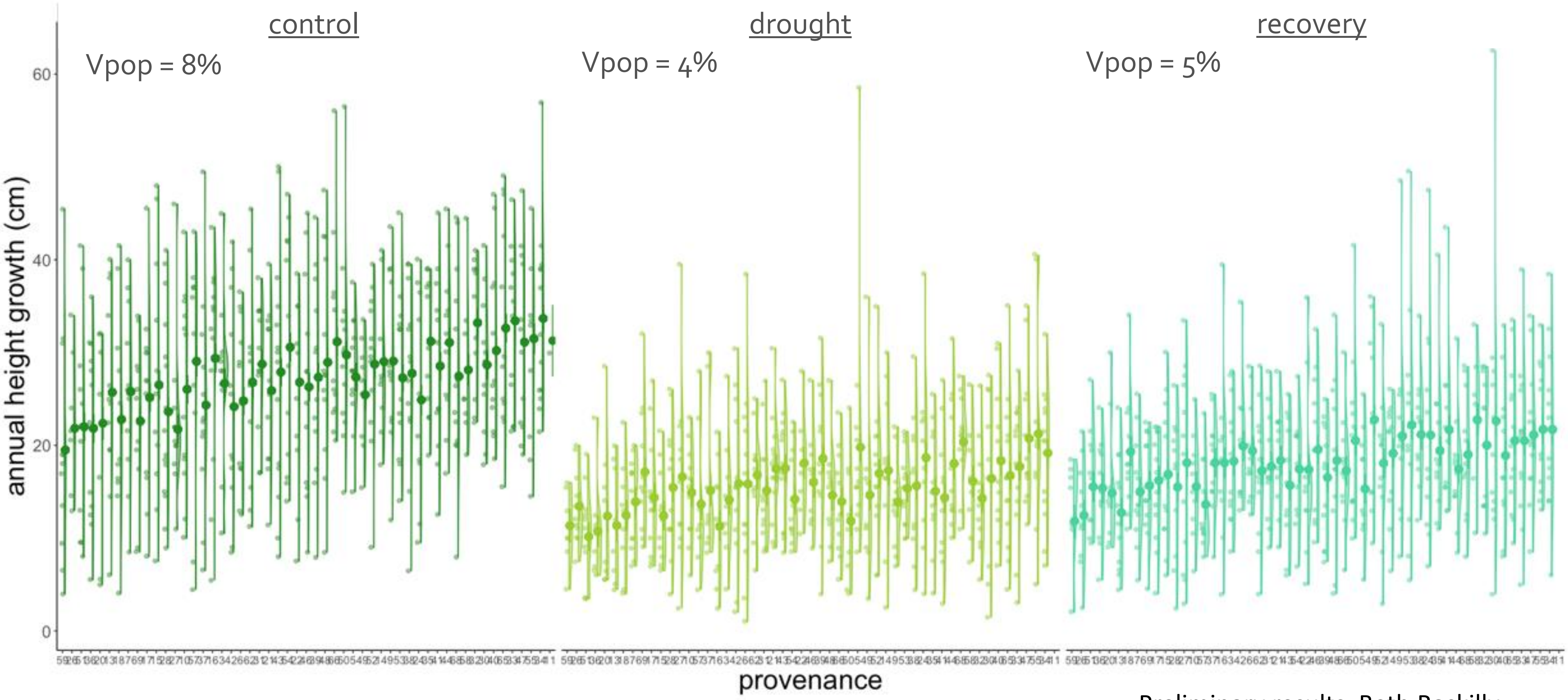
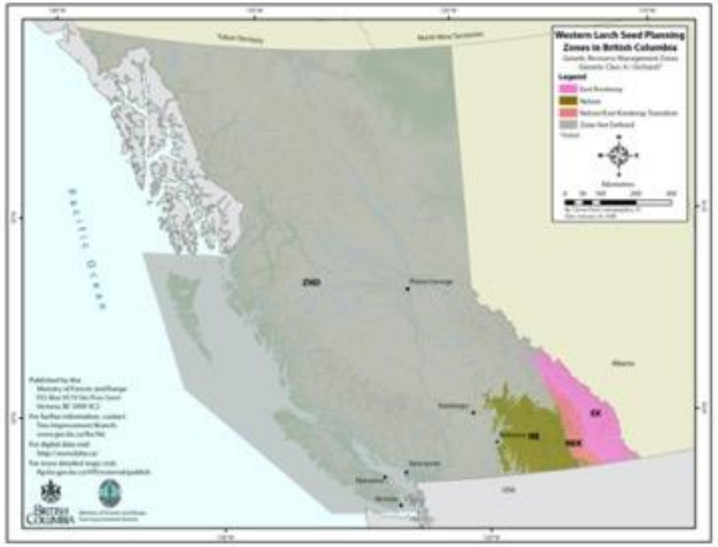
Preliminary results, Beth Roskilly

Weak variation among larch provenances (Vpop 5-8%); Less variation in drought and recovery treatments

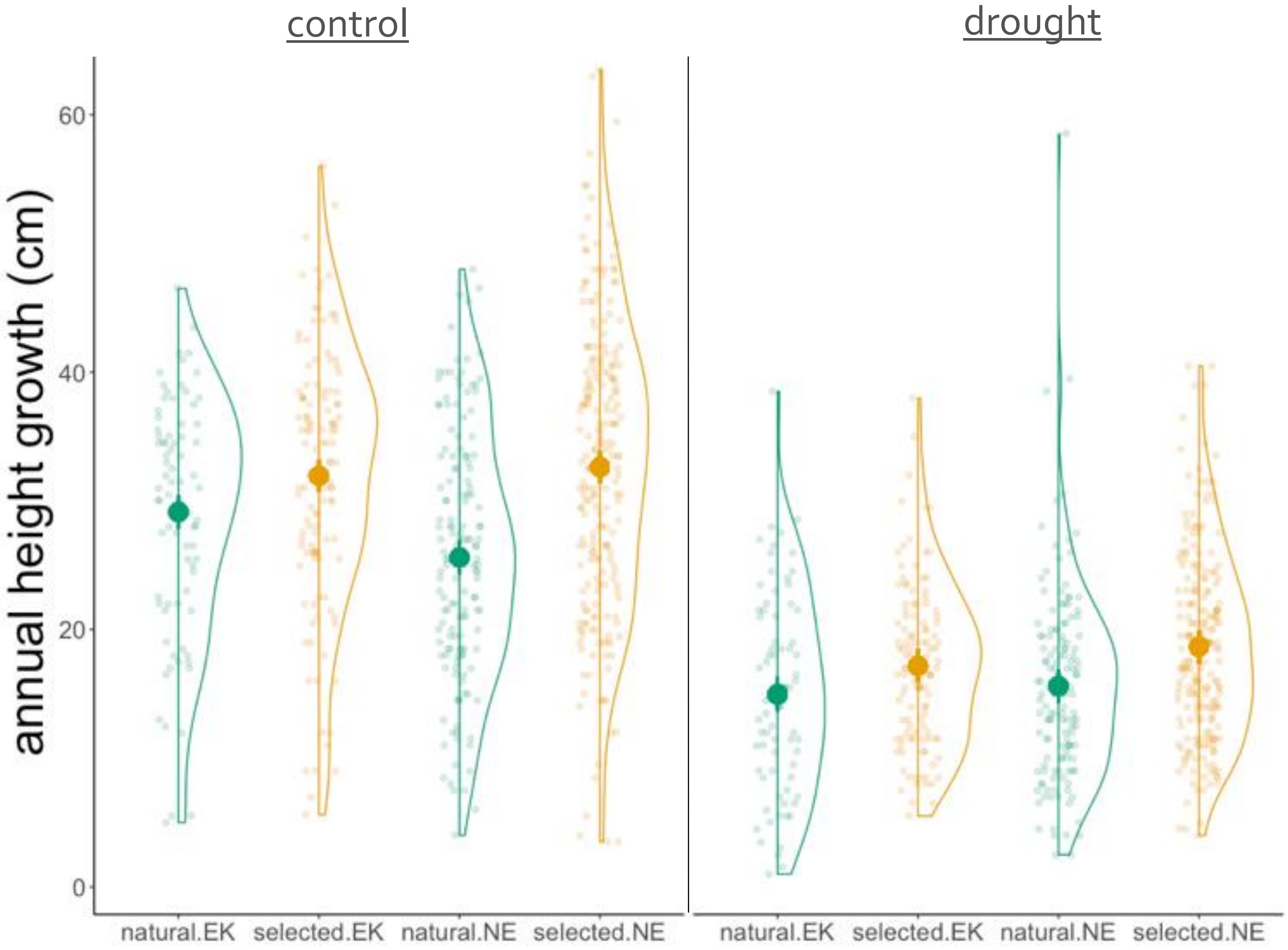


Preliminary results, Beth Roskilly

Selected families have greater **height growth** compared to natural populations but differences are reduced in drought and recovery treatments

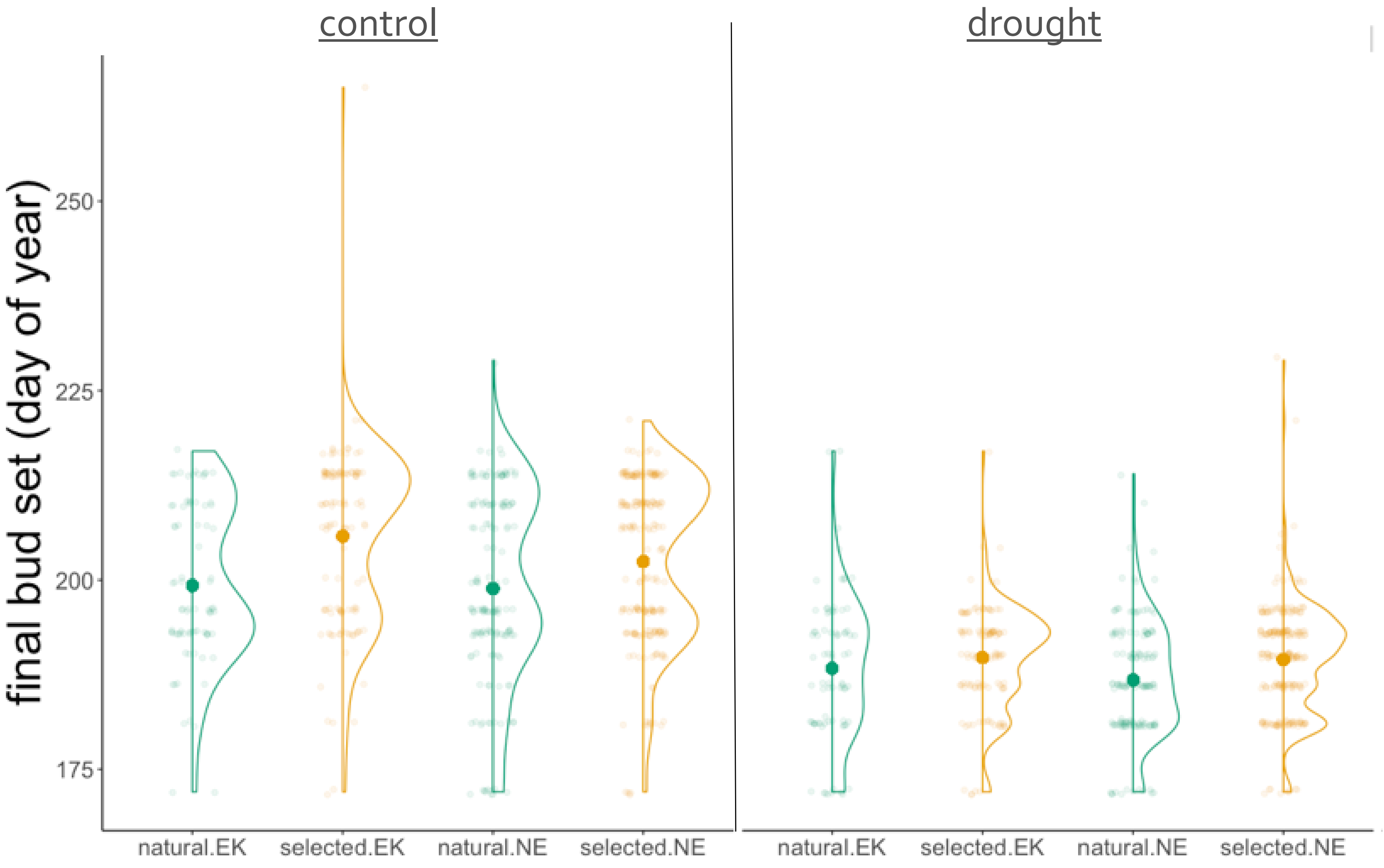


Larch breeding populations
EK and NE



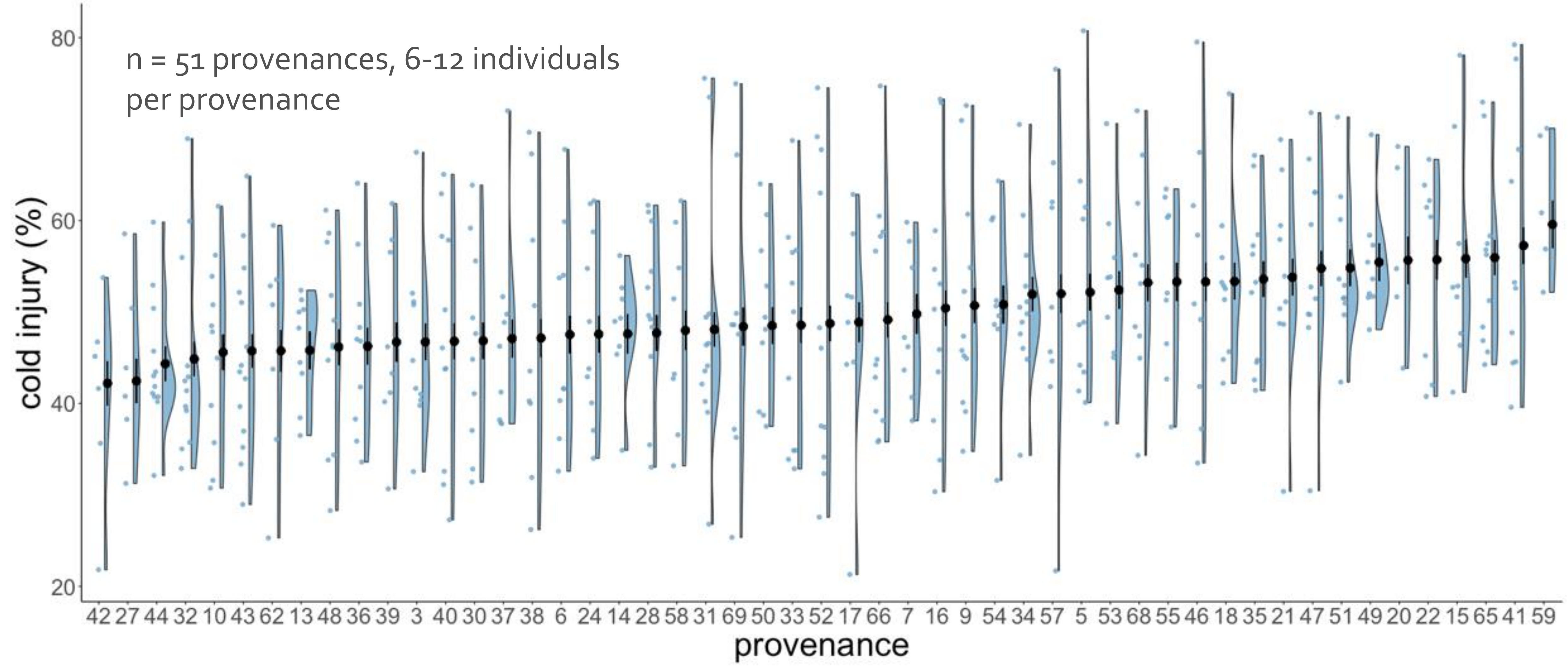
Preliminary results, Beth Roskilly

Selected families achieve greater height growth through later **final budset** than natural populations in control treatment but not under drought



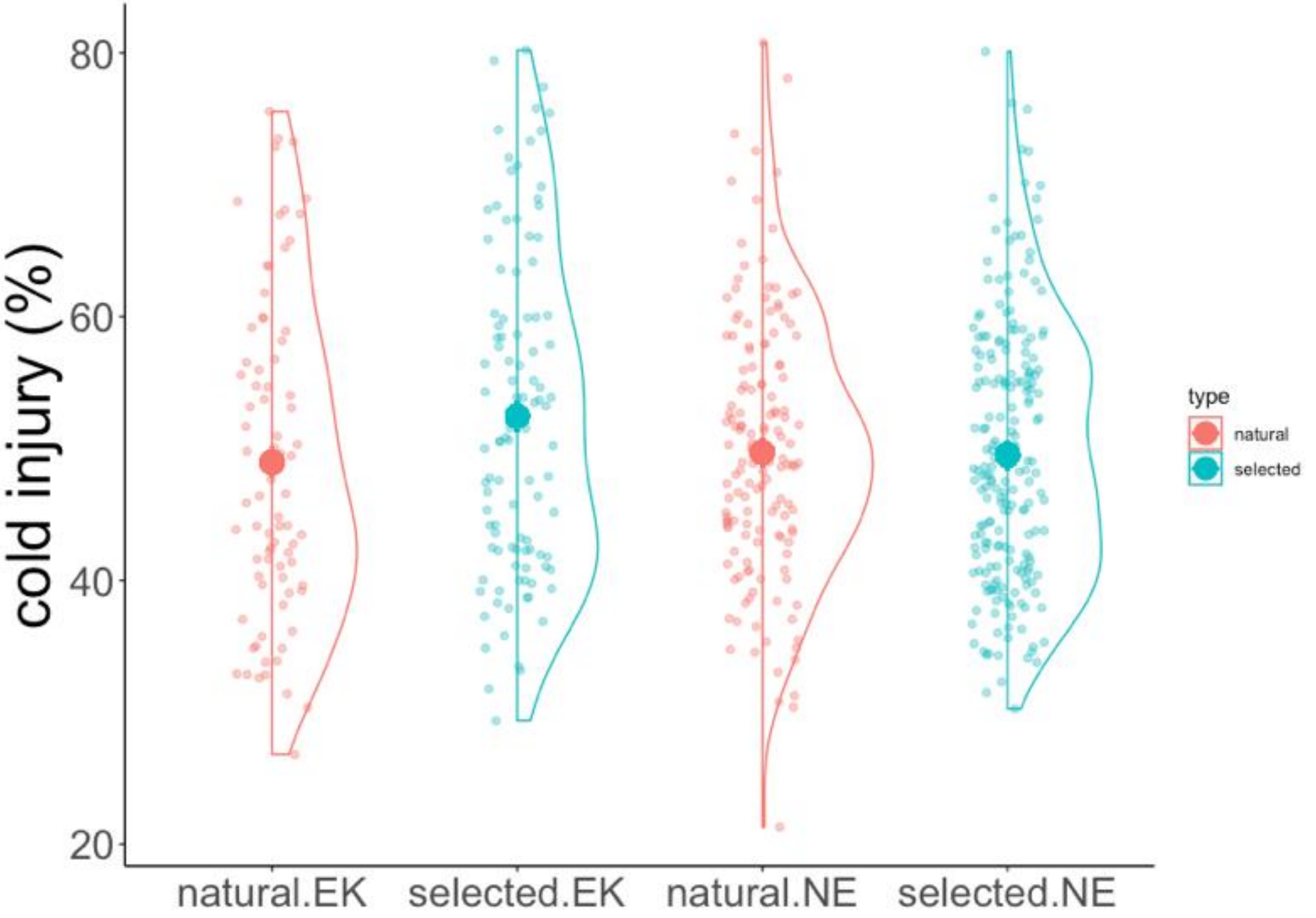
Preliminary results, Beth Roskilly

Little variation among provenances for **fall cold injury** in artificial tests



Preliminary results, Beth Roskilly

Cold injury is slightly greater in selected families compared to natural populations from East Kootenay but not Nelson breeding zone.



n = 8 n = 10 n = 16 n = 18

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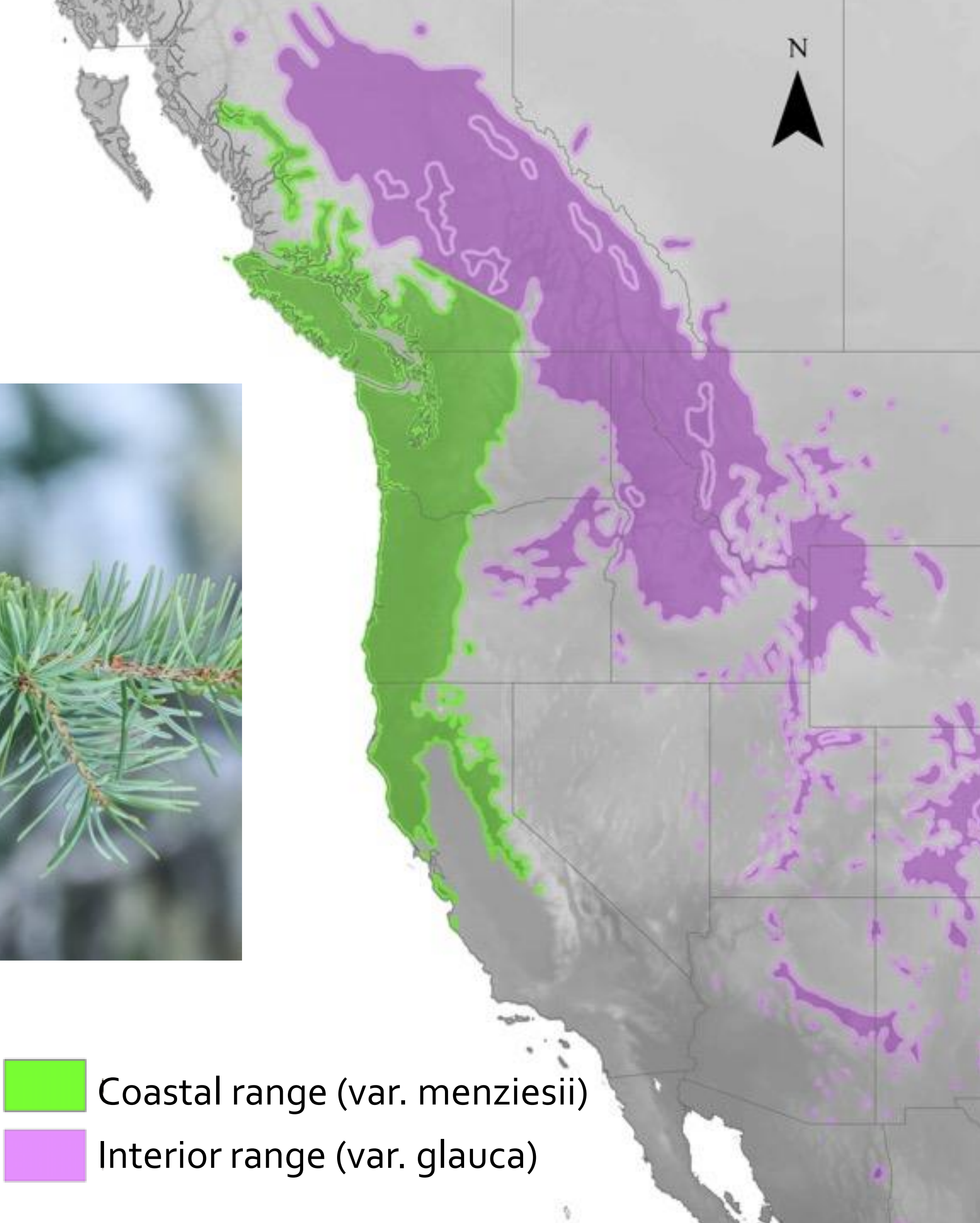
Preliminary results, Beth Roskilly

Climate adaptation in Douglas-fir

Rafael Ribeiro, PhD candidate



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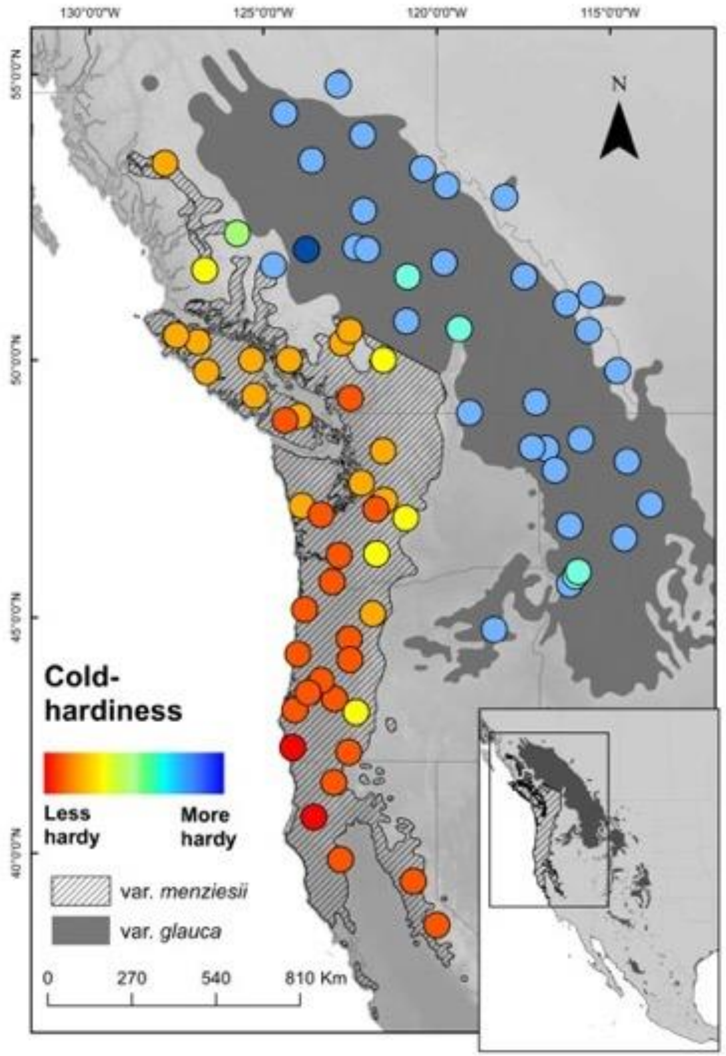
Substantial variation in cold hardiness both between varieties and among populations within varieties in Douglas-fir



Cold hardiness in 87 populations of coastal and interior Douglas-fir

PhD research of Rafael C. Ribeiro

Drought experiment testing for provenance differences

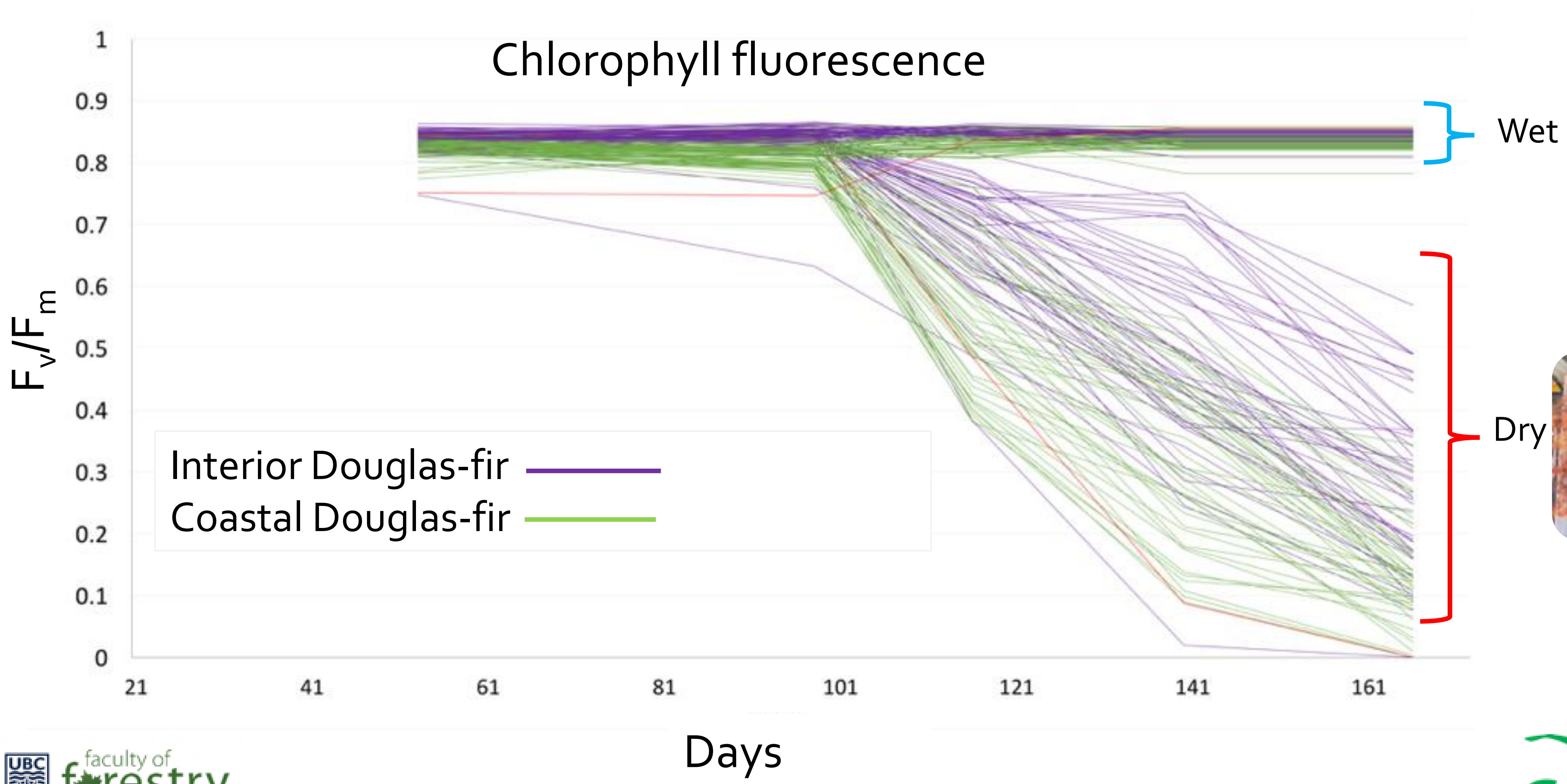
May 2018 (≈45 days) | Jun 2018 (≈75 days) | Jul 2018 (≈100 days) | Aug 2018 (≈135 days) | Sep 2018 (≈150 days)

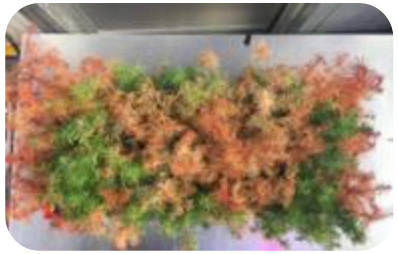
UBC faculty of forestry university of british columbia

PhD research of
Rafael C. Ribeiro

CoAdapTree
Healthy Trees for Future Climates

Douglas-fir drought hardiness: 87 populations





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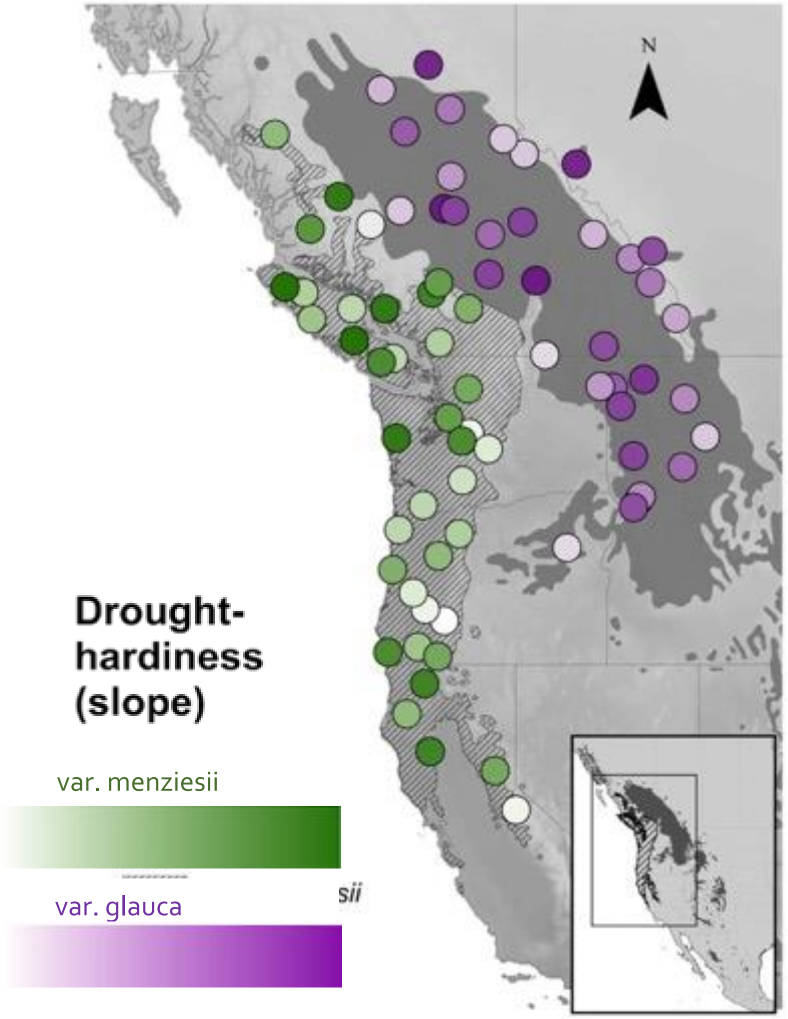
Drought tolerance varies between Douglas-fir varieties (V_{pop}=18%); among-provenance variation only within interior Douglas-fir

Coastal

Source of Variance	Drought hardiness
Provenance	1%
Block	0%
Residual	99%
Vpop	1%

Interior

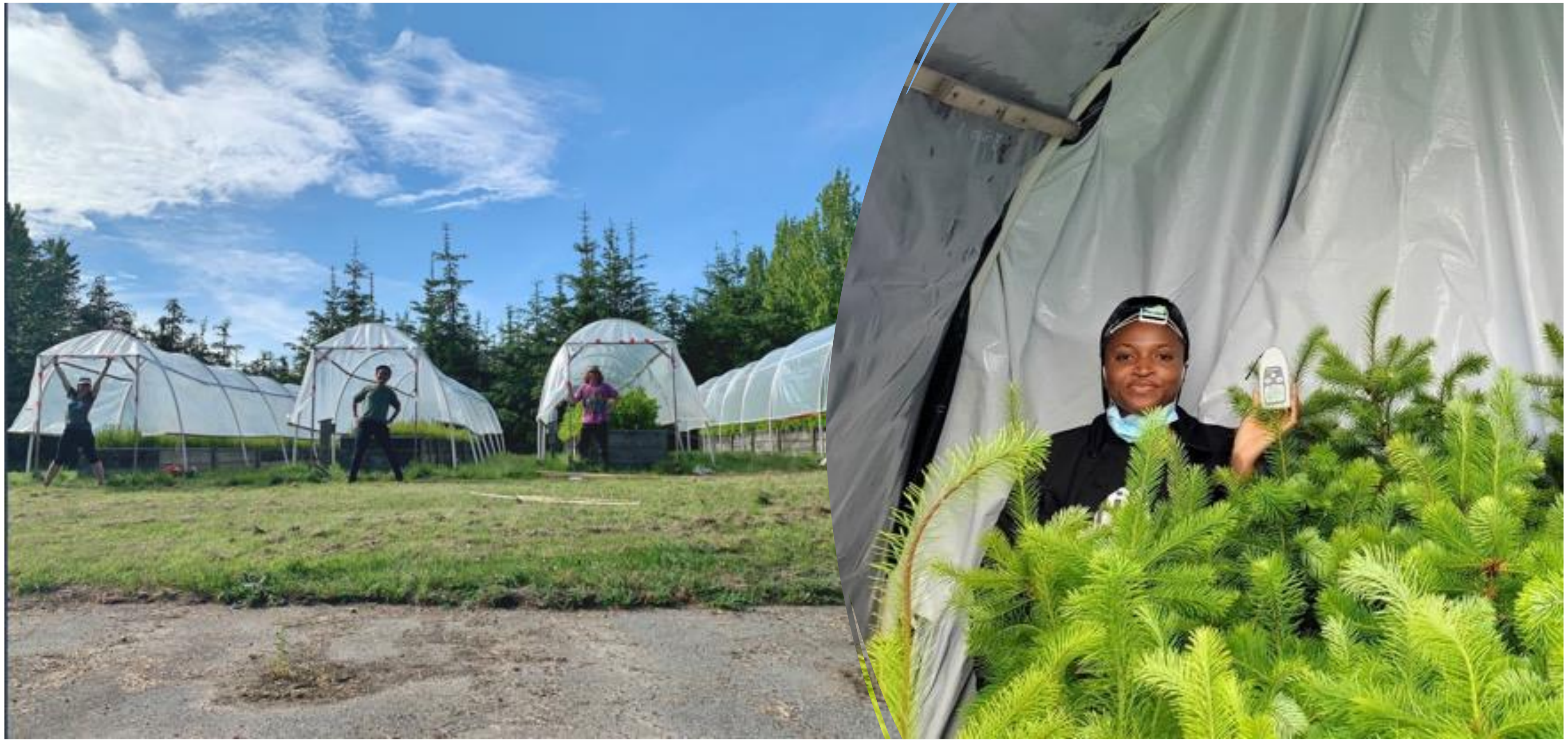
Source of Variance	Drought hardiness
Provenance	12%
Block	1%
Residual	87%
Vpop	13%



R. Ribeiro, Unpublished results

Tested variation in drought tolerance among select interior and coastal Douglas-fir families from breeding programs

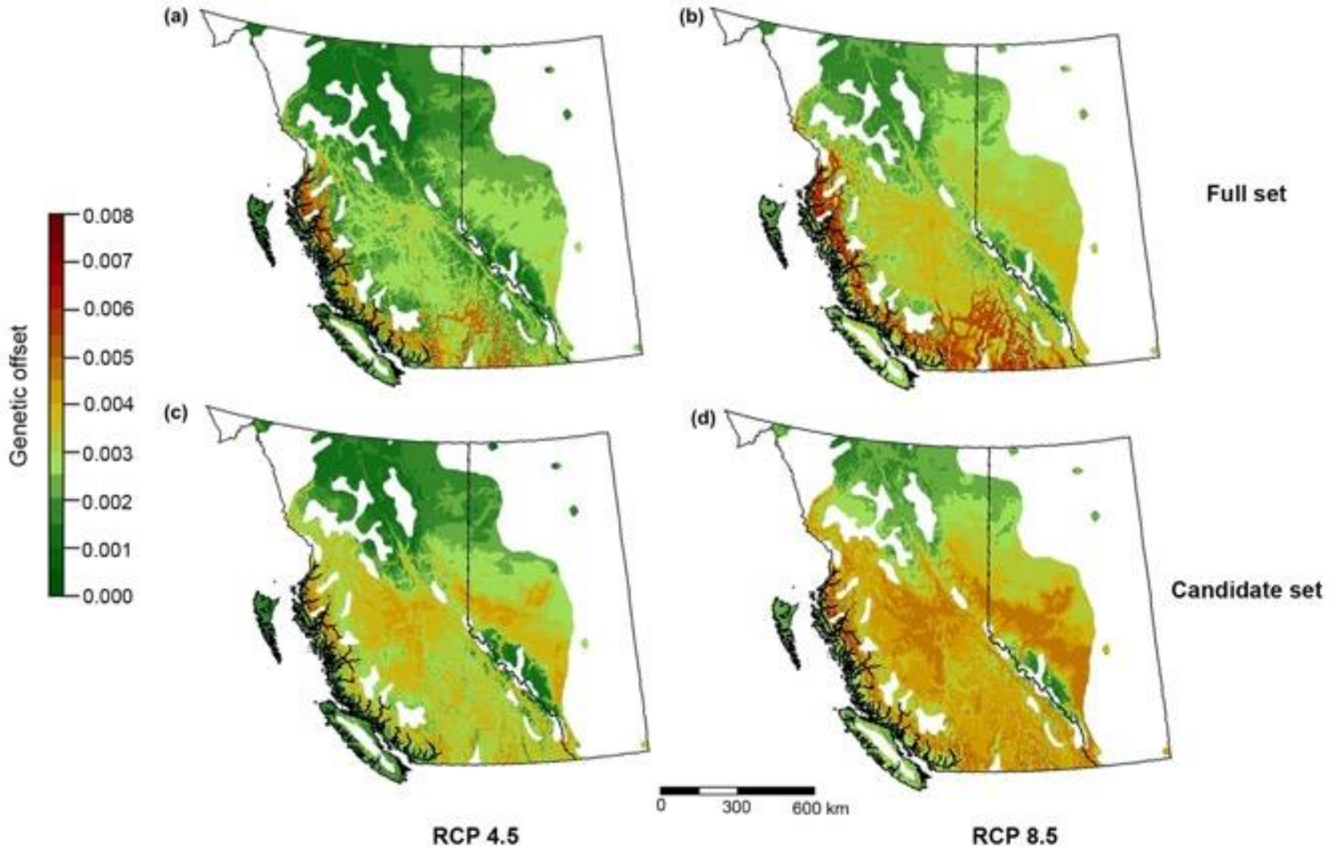
Judith Nuhu, MSc student



Judith Nuhu

Using genomic data to predict maladaptation with climate change in Douglas-fir and lodgepole pine

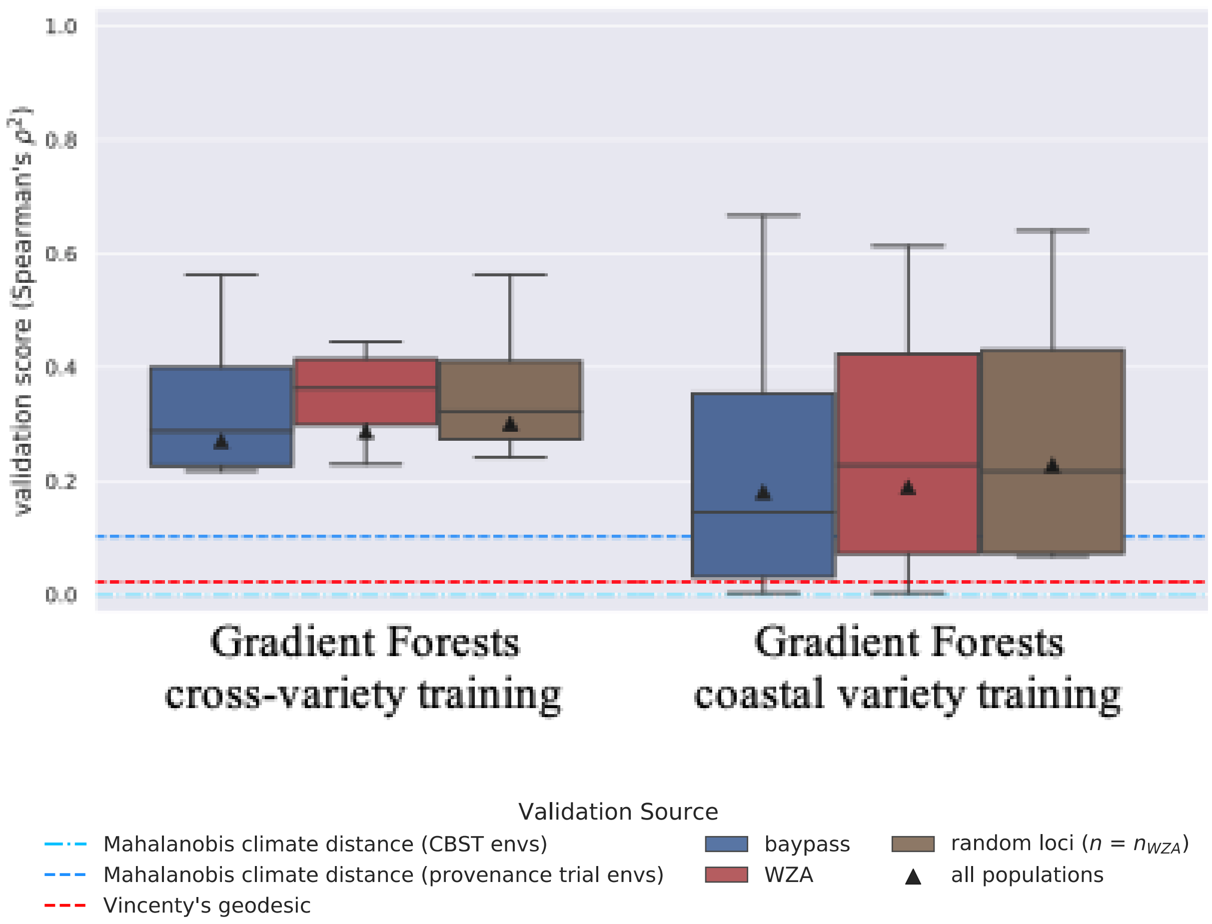
Example: Lodgepole pine (Yue Yu, MSc thesis with Tongli Wang)



Yu et al. submitted

Using genomic data to validate predictions of maladaptation with phenotypic data from Douglas-fir

Example: Douglas-fir (Brandon Lind, postdoctoral fellow)



CBST climate distance

Geographic distance

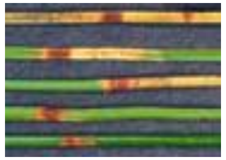
Lind et al. In prep.

Genes for tolerance of Dothistroma needle blight (DNB) in lodgepole pine

Susceptibility to DNB →

Most resistant

Least resistant



Richard Hamelin, Nicholas Feau, Nick Ukrainetz, Mengmeng Lu and others

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CoAdapTree

Genomic tool for Douglas-fir and lodgepole pine breeding: CoAdapTree Douglas-fir/lodgepole pine Axiom ~50K SNP array

- Markers split equally between lodgepole pine and Douglas-fir
- Includes SNPs distributed across genomes for genomic selection or other applications
- In use for validating genetic markers for drought, cold, Dothistroma and Swiss needle cast tolerance

Species	Selection criteria	Number of genes
Douglas-fir	Climate associated	3,956
	Drought associated	1,167
	Cold injury associated	781
	Disease associated	1,026
Lodgepole pine	Climate and climate-related trait associated	5,766
	Disease associated	1,260

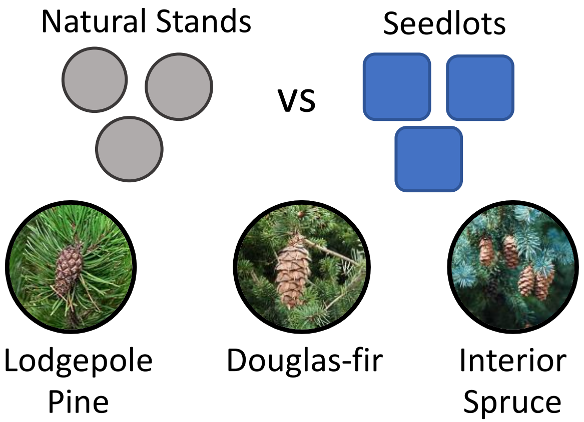
Landscape Diversity Project (GeneSolve - GenomeBC)

Hayley Tumas, Postdoctoral Fellow

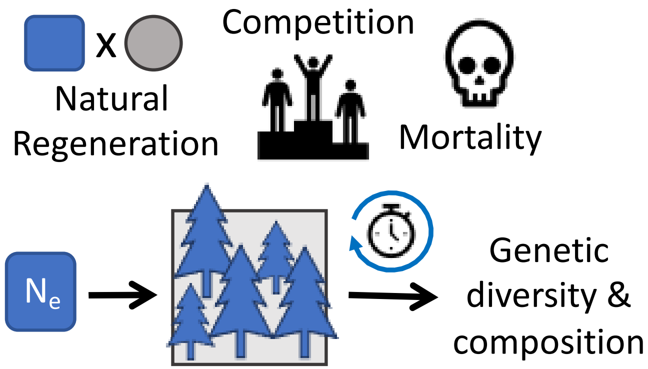
Genome BritishColumbia

BRITISH COLUMBIA | Ministry of Forests, Lands, Natural Resource Operations and Rural Development

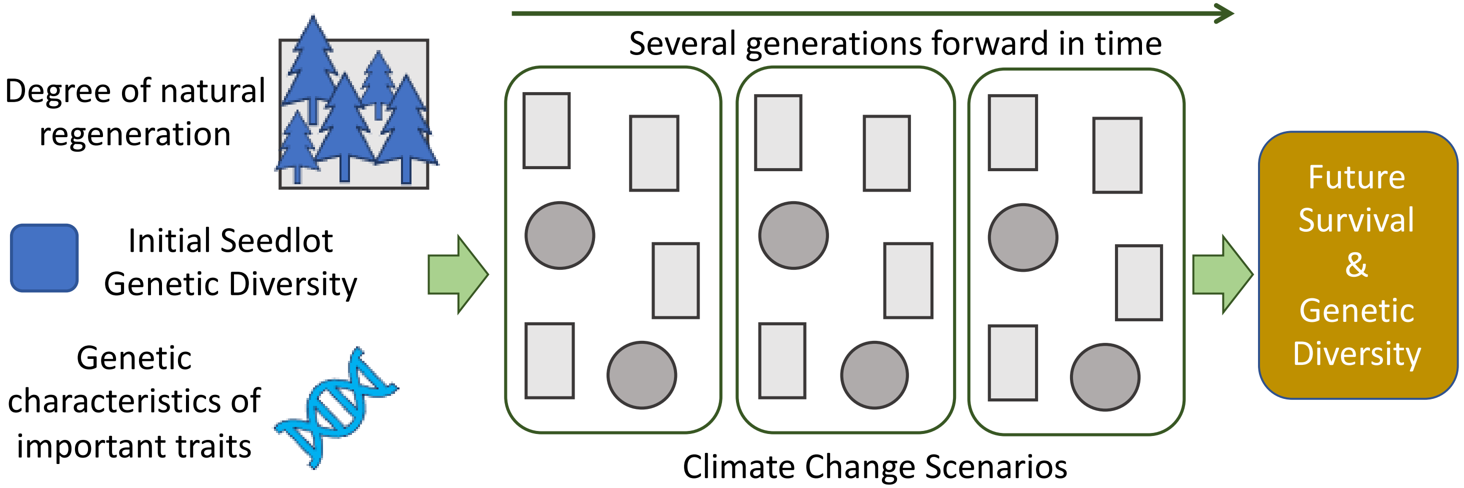
1.) Assess current genetic diversity.



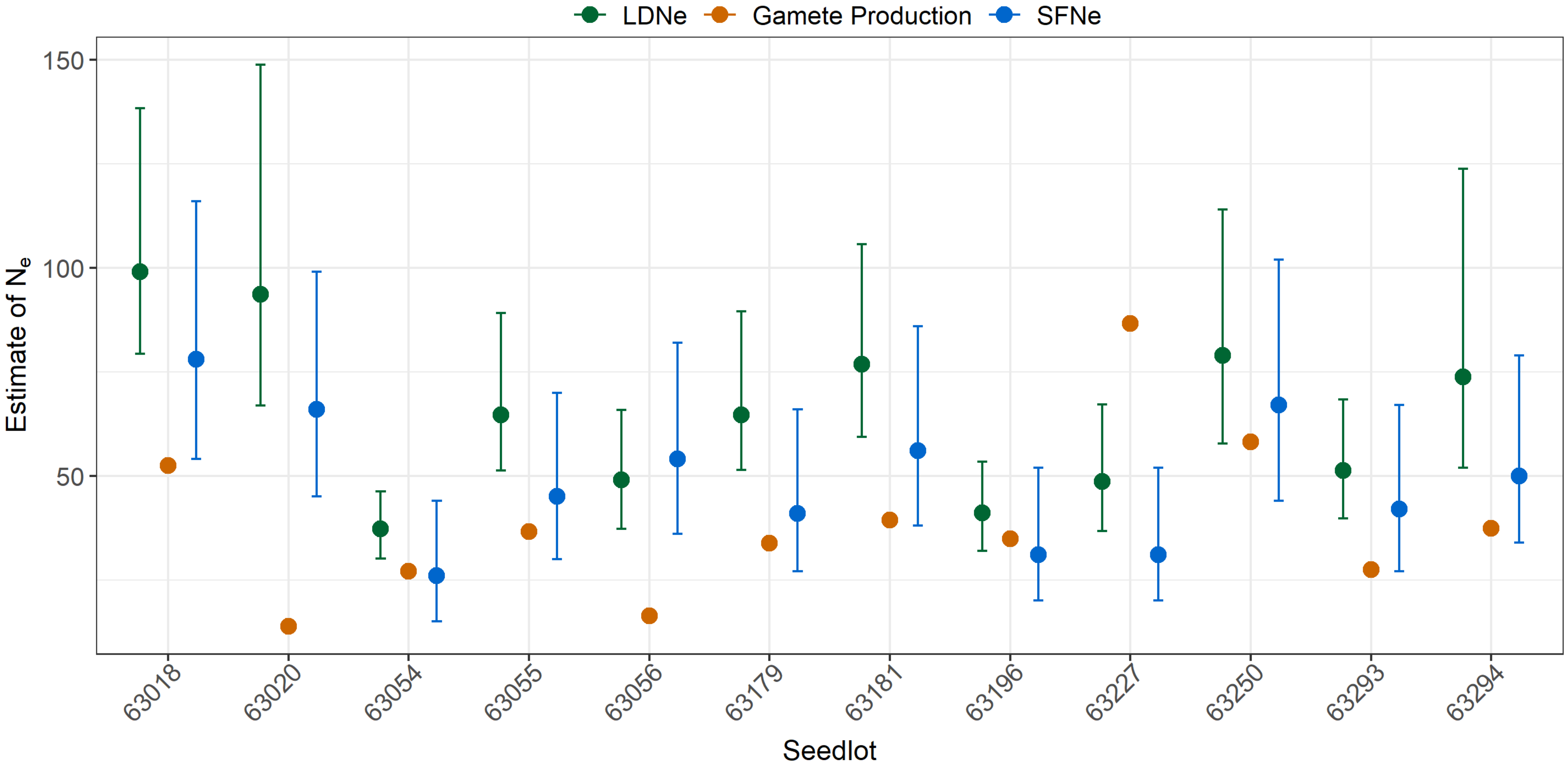
2.) Examine genetic diversity and composition of mature stands.



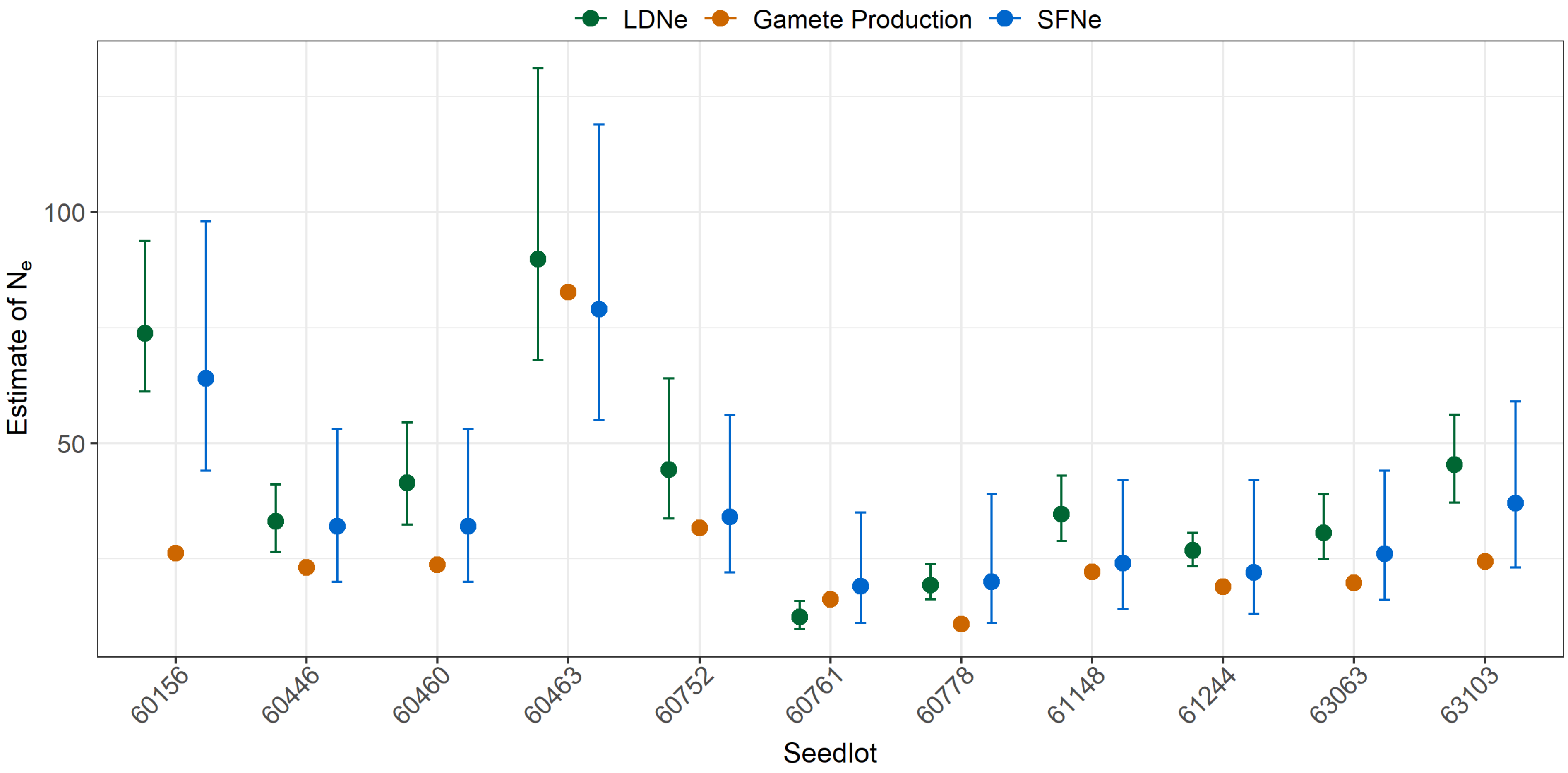
3.) Use a simulation model to predict future genetic diversity.



Genomic versus SPAR Effective Population Size Estimates for Orchard Seedlots – lodgepole pine



Genomic versus SPAR Effective Population Size Estimates for Orchard Seedlots – interior spruce



Summary

- Modest provenance variation for drought tolerance in Fdi but not Fdc
- Larch shows weak provenance variation in seedling common gardens as well as field trial
- Selectively bred larch families achieve greater growth through plasticity and delayed final bud set when water is available
- CoAdapTree SNP array for Douglas-fir and pine has markers for genes associated drought and cold tolerance, climate associations and disease tolerance
- Preliminary results suggest SPAR estimates of effective population size are reasonable and conservative
- A close look at genetic diversity at the landscape level is underway

Acknowledgements

CoAdapTree
Healthy trees for future climates

Beth Roskilly
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VirginiaTech
Alberta Innovates Bio Solutions
The University of California Davis
VSOC Vernon Seed Orchard Company
FGC Forest Genetics Council of British Columbia
CANFOR
West Fraser
Natural Resources Canada
Ressources naturelles Canada
NSERC CRSNG
WFP Western Forest Products Inc.
TimberWest
Centre for Forest Conservation Genetics
CFCG