Phenotypic Selection of Growth Rhythm in Whitebark Pine (*Pinus albicaulis*) Under Warm-Dry Climate.

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Photo by: Daniel Cassman

Motive

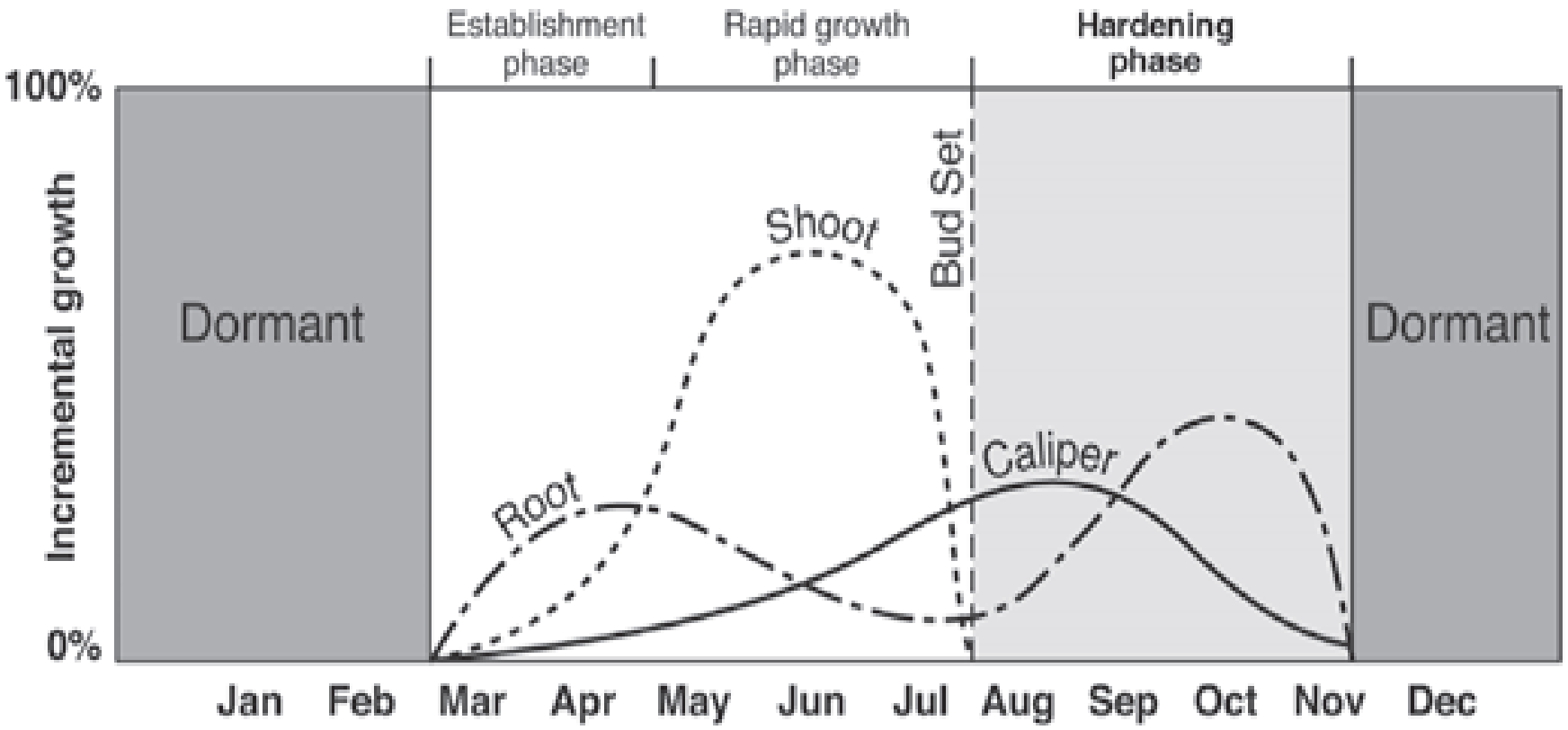
- Most major temperate and boreal forest tree species exhibit unique patterns of adaptation to climate (Mogenstern 1996).

- Ongoing rapid climate change threatens to disrupt these patterns resulting in widespread maladaptation (Rehfeldt et al. 2006)

Overview

- Genecology of Whitebark Pine
- Phenotypic Selection of Growth Rhythm in Whitebark Pine
- Phenotypic Selection in Ponderosa Pine Under Three Experimentally Imposed Drought Treatments

Growth Rhythm



modified from Landis and others 1999

The timing of annual growth and dormancy events

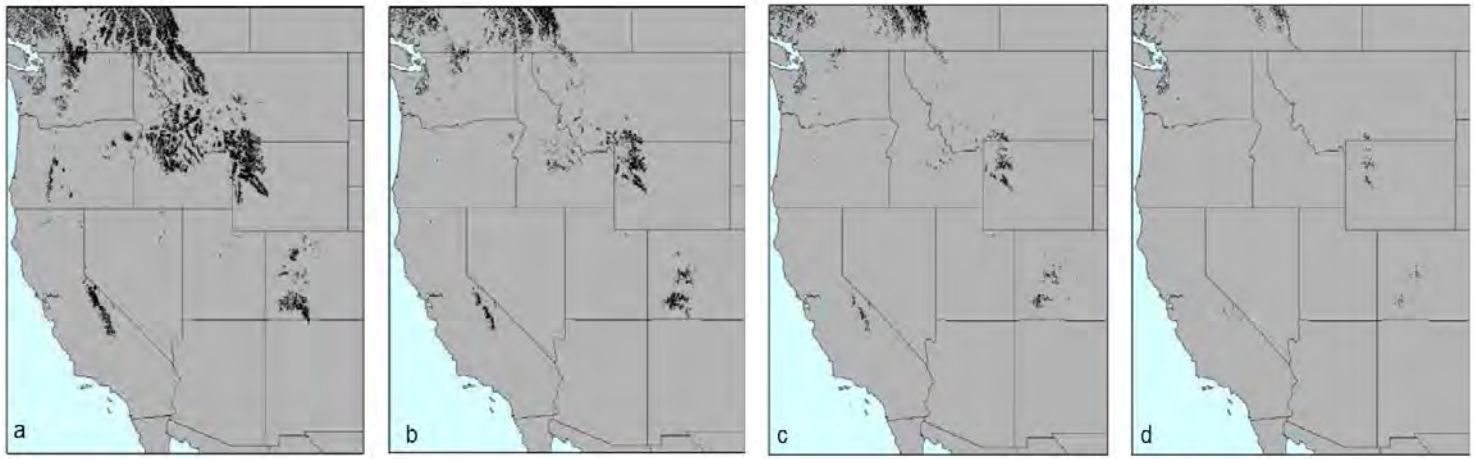
Connie Harrington and Peter Gould at the FS Olympia lab

Connie Harrington and Peter Gould at the FS Olympia lab

Climate Change

Whitebark Pine

1961-1990 **2030** **2060** **2090**



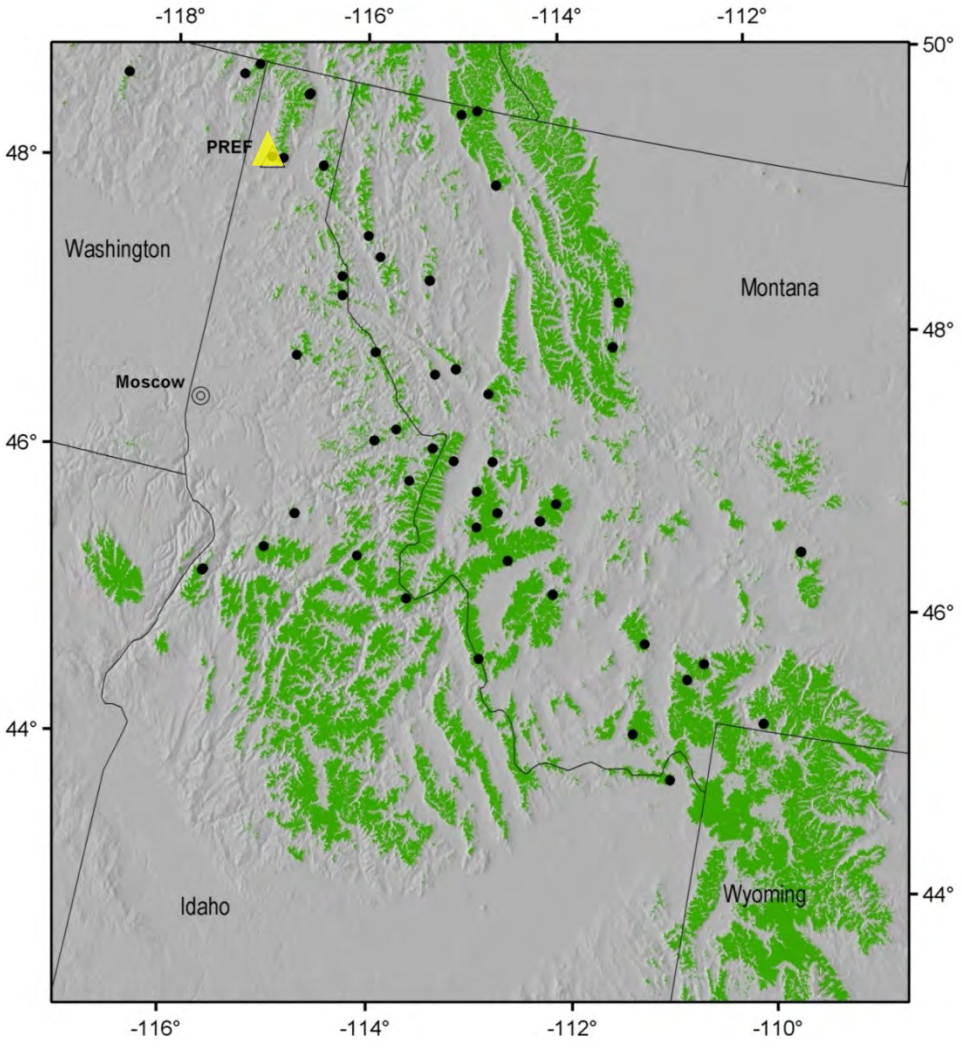
(Warwell *et al.* 2006)

∆ area ≈ 97%

Research Question

- What is the form, magnitude, and tempo of phenotypic selection on growth rhythm under climate warmer and drier than the climate of seed origin?

Study Region



Modeled Whitebark Climatic Habitat

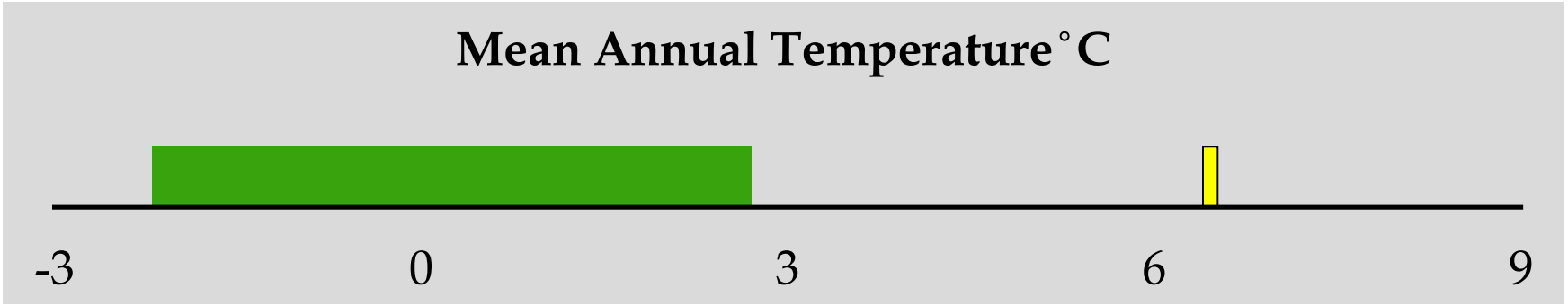
Study Seed Sources

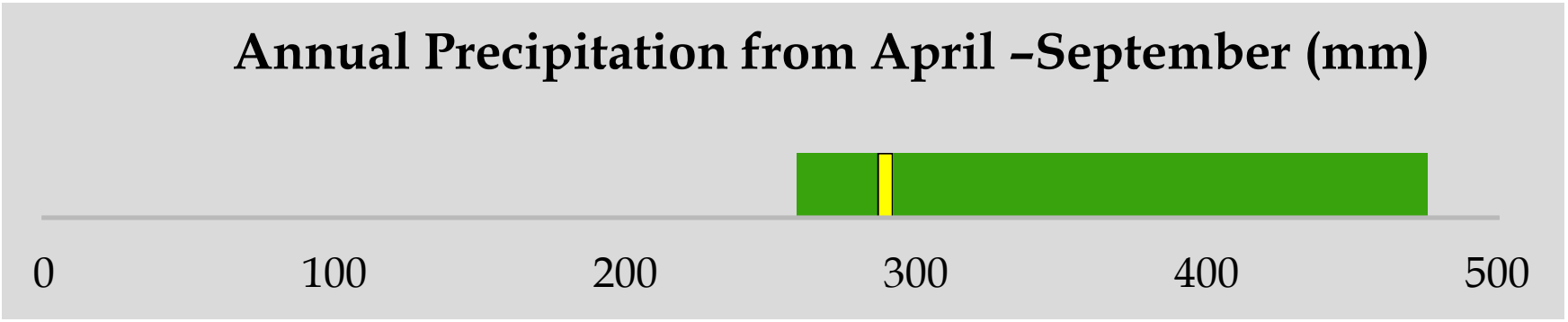
Study Site

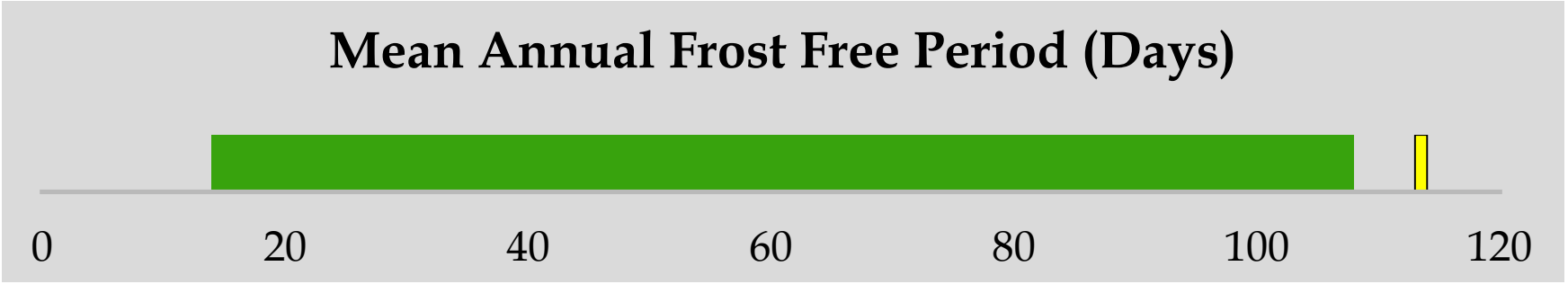
Mean Climate Range of Seed Sources

vs.

Mean Climate of Study Site







Common Garden Experiment 1

- 46 seed sources 1,350 seedlings
- Outplanted spring, 2000 (2 yr. old stock)
- Randomized complete block design
- 6 replications of 5 tree row-plots per population

Summer 2000

Fall 2012

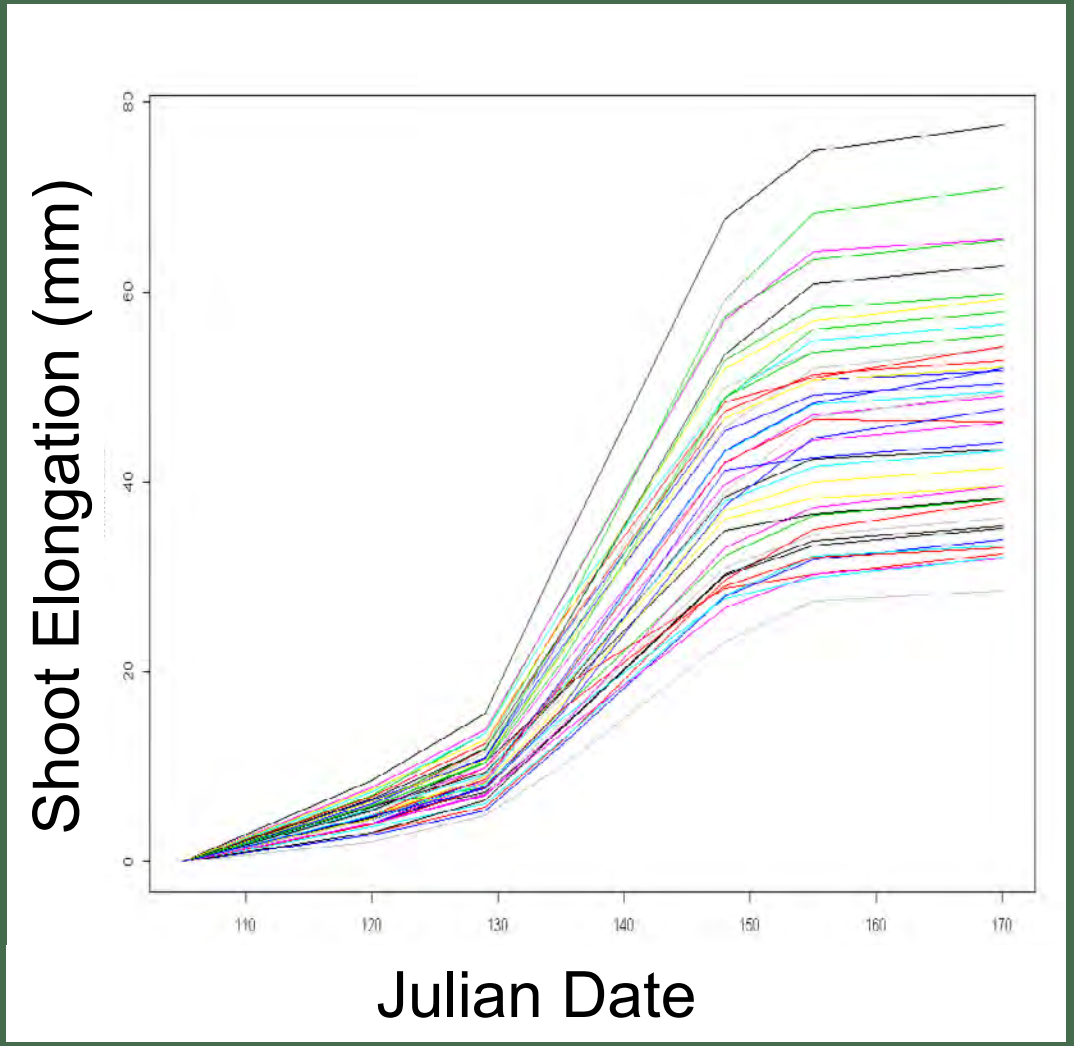
Common Garden Experiment 2

- 42 seed sources, 963 seedlings
- Outplanted fall 2001
- Randomized complete block design
- 3 replications of 10 tree row-plots per population

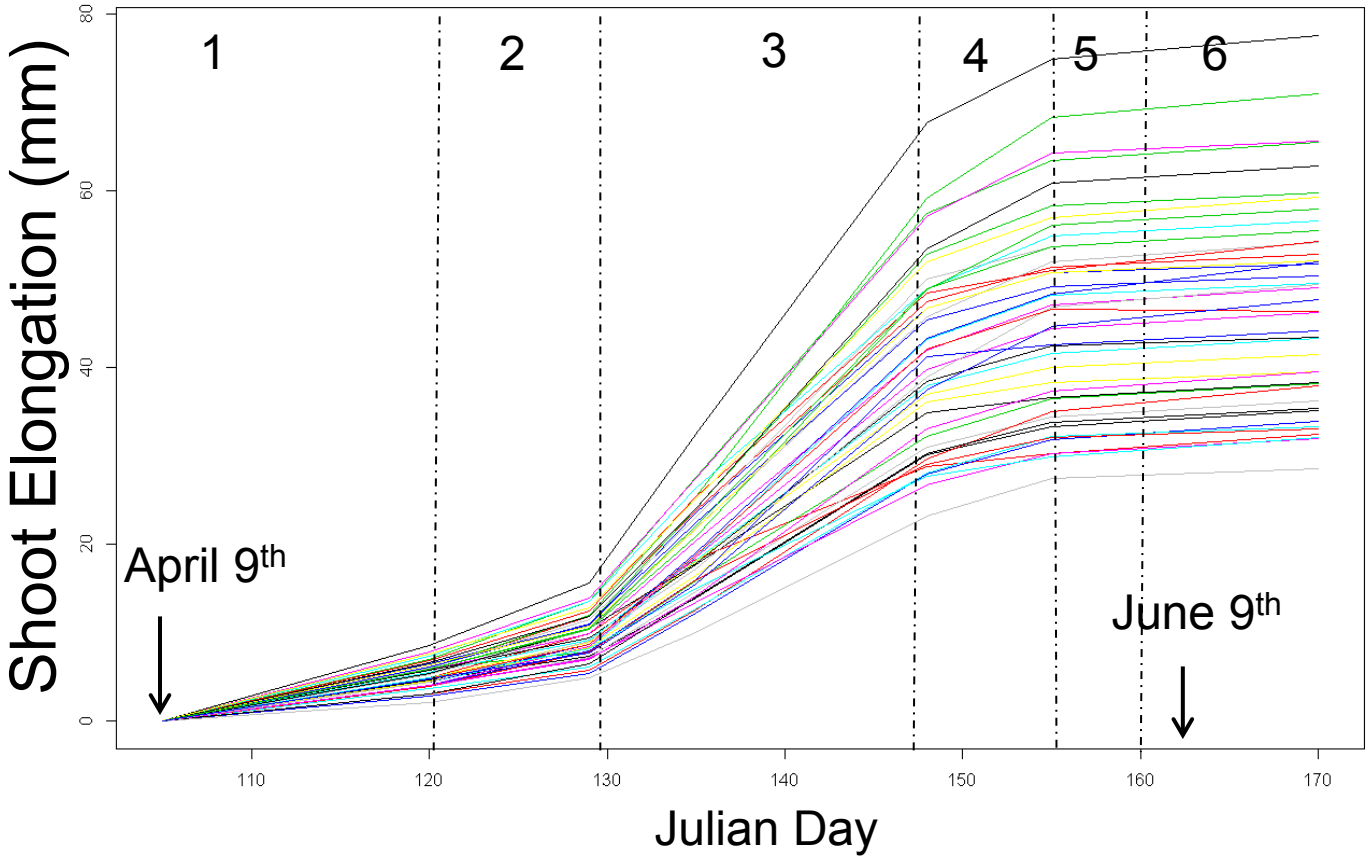
Fall 2001

Spring 2010

Incremental Shoot Elongation

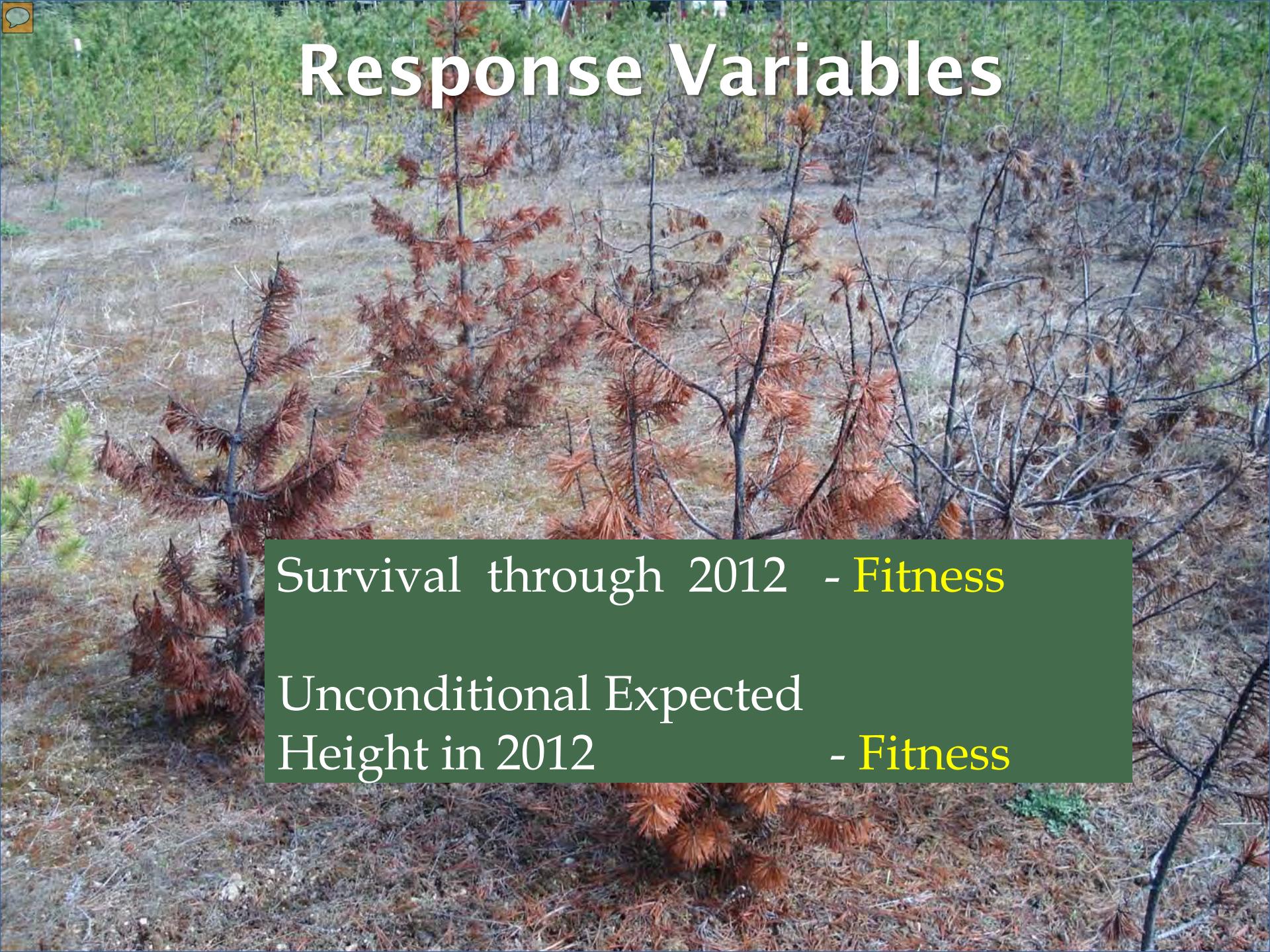


Selection analysis using intervals of elongation rates



- Backward stepwise regression in a standard Lande and Arnold (1883) fitness regression approach

Response Variables



Survival through 2012 - Fitness

Unconditional Expected Height in 2012 - Fitness

Unconditional Expected Height ≈ Fitness

Experiment 1

Survival Fall 2002 → Survival Fall 2003 → Survival Fall 2004 → Survival Fall 2005 → Survival Fall 2011 → Survival Fall 2012 ↓ Height Fall 2012

- Inferred using aster analysis which provides statistically rigorous, unified analysis of joint life history data (Geyer and Shaw 2008)

Unconditional Expected Height ≈ Fitness

Experiment 1

Survival Fall 2002 → Survival Fall 2003 → Survival Fall 2004 → Survival Fall 2005 → Survival Fall 2011 → Survival Fall 2012 ↓ Height Fall 2012

- Height estimates are considered unconditional because they explicitly include mortality in their estimate.

Unconditional Expected Height ≈ Fitness

Experiment 1

Survival Fall 2002 → Survival Fall 2003 → Survival Fall 2004 → Survival Fall 2005 → Survival Fall 2011 → Survival Fall 2012 ↓ Height Fall 2012

- Survival was modeled using Bernoulli and height was modeled using normal distributions

Unconditional Expected Height ≈ Fitness

Experiment 1

Survival Fall 2002 → Survival Fall 2003 → Survival Fall 2004 → Survival Fall 2005 → Survival Fall 2011 → Survival Fall 2012 ↓ Height Fall 2012

- Following initial survival, each successor variable was modeled using its predecessors sample size

Unconditional Expected Height

Seed Source	Survival	Mean Height	Unconditional Expected Height
Powell Mine, MT			546 mm
Beaver Creek, ID	-11%	+ 339 mm	546 mm

- Differences in survival are accounted for in estimates of unconditional height.

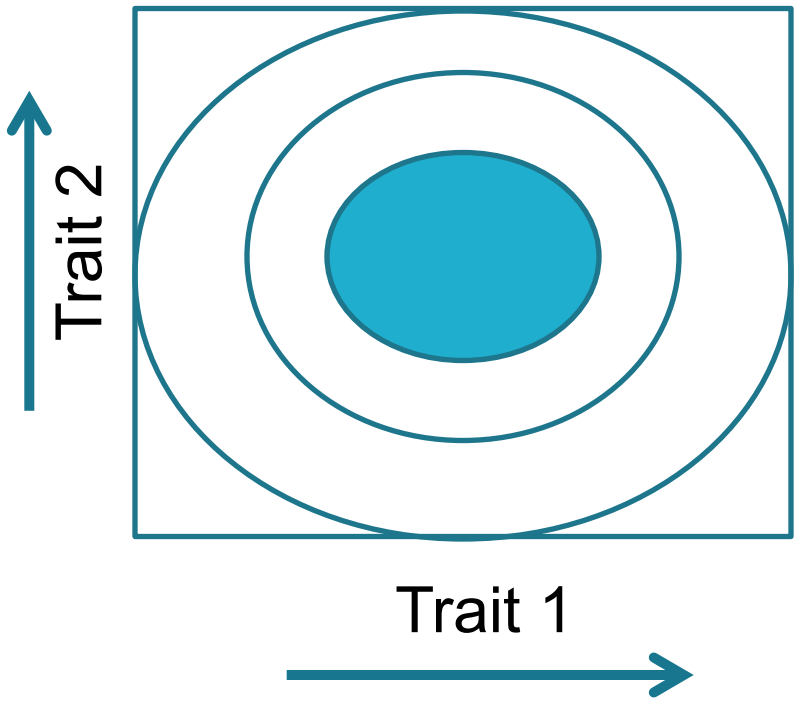
General Performance

Exp.	Survival in 2012	Height of Survivors in 2012
1	39%	1056 mm
2	41%	854 mm

Phenotypic Selection

- Form

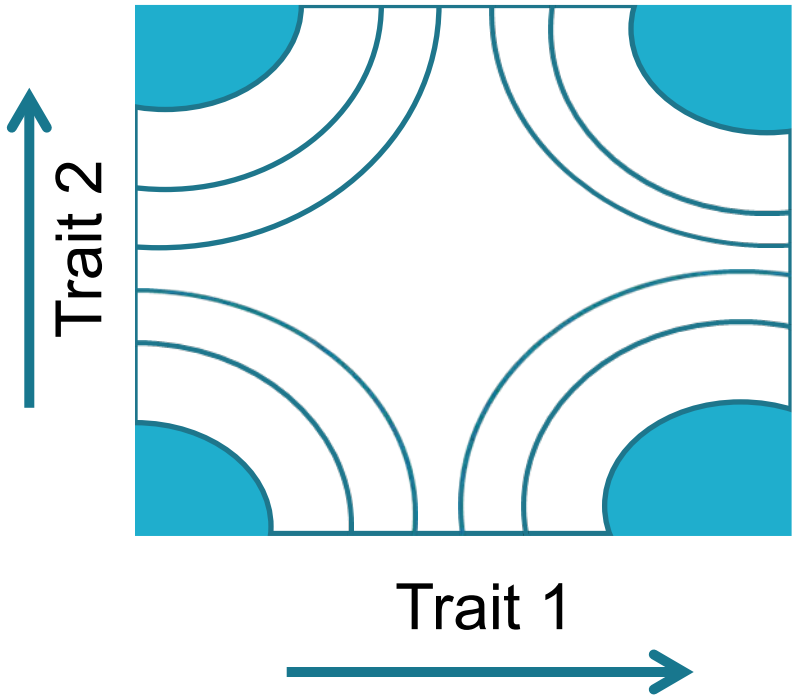
Stabilizing Selection



Phenotypic Selection

- Form

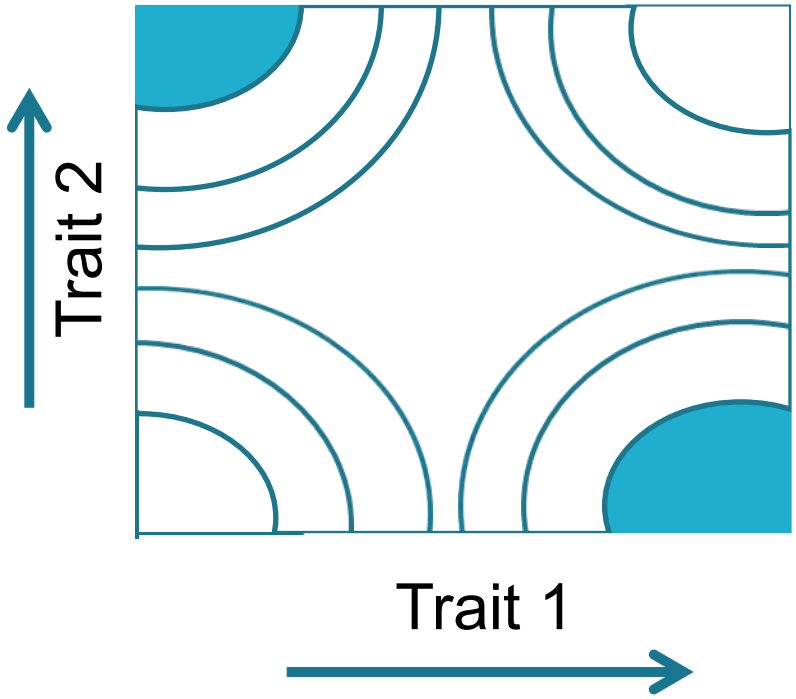
Disruptive Selection



Phenotypic Selection

- Form

Disruptive Selection



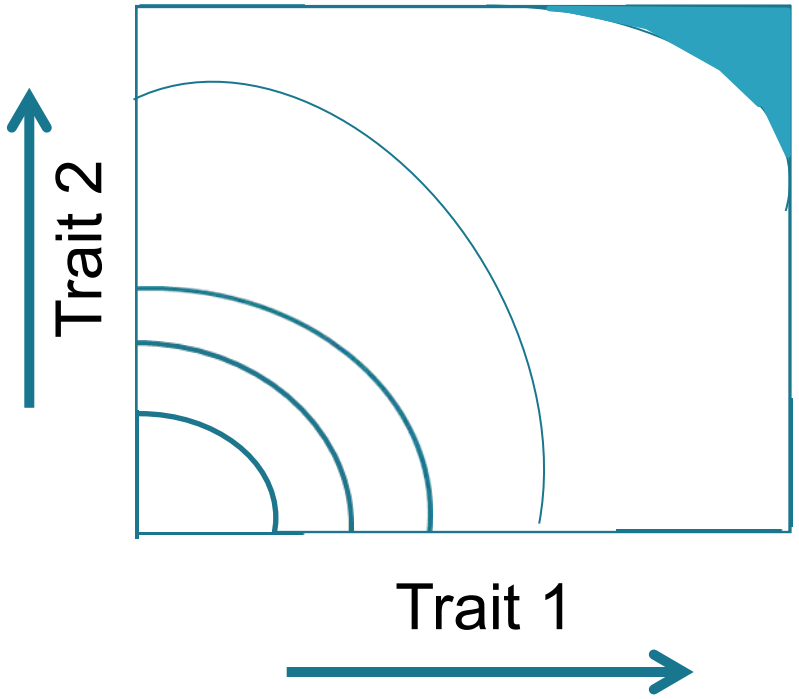
Phenotypic Selection

- Form, Magnitude and Tempo ?

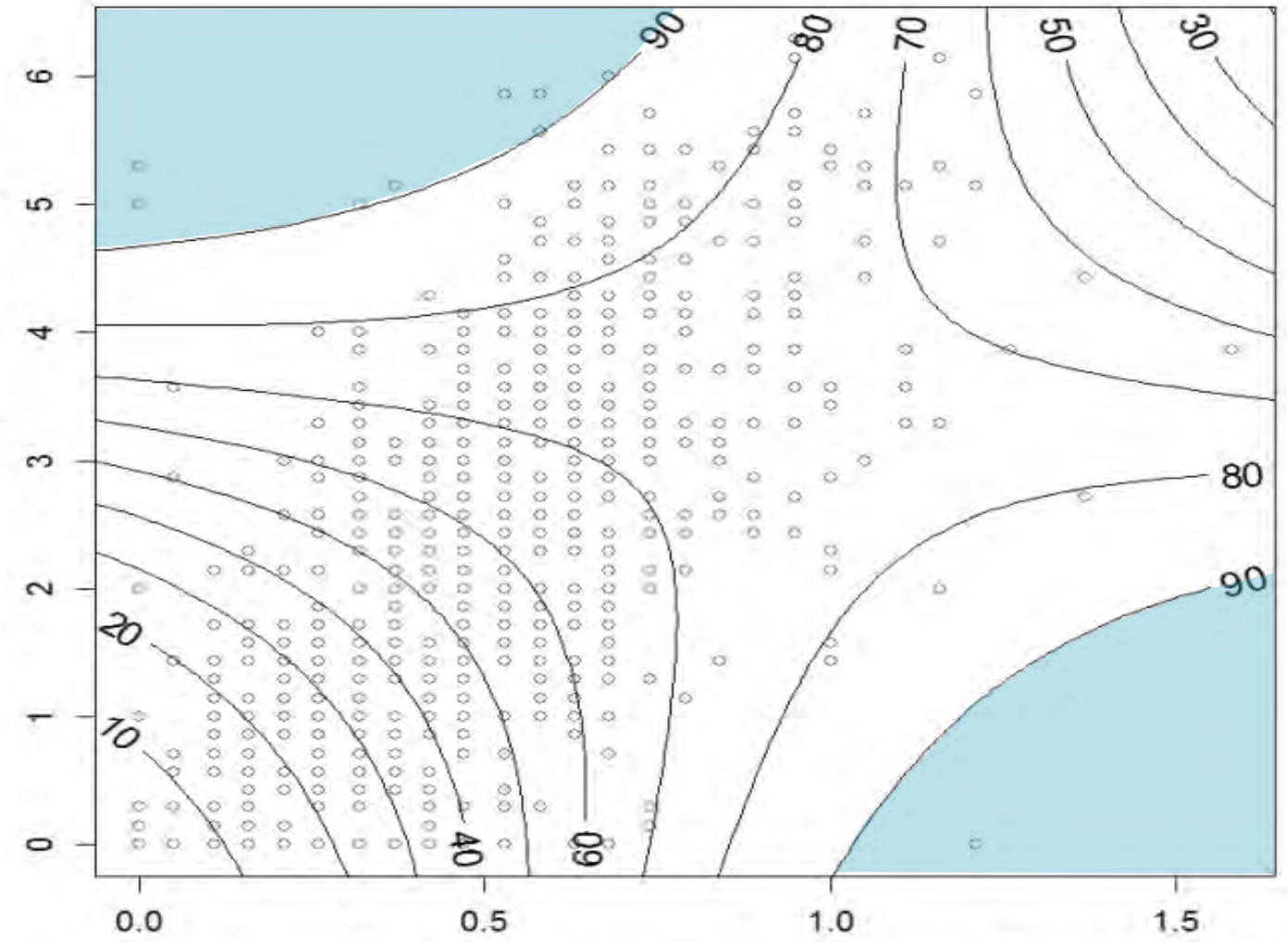
- Can be used to estimate short term evolutionary trajectory when heritability Information is available (Falconer and Mackay 1996)

$$R = h^2 S$$

Directional Selection



Experiment 1: Fitness Surface (% Survival 2002-2012) for Shoot Elongations Rate in 2002



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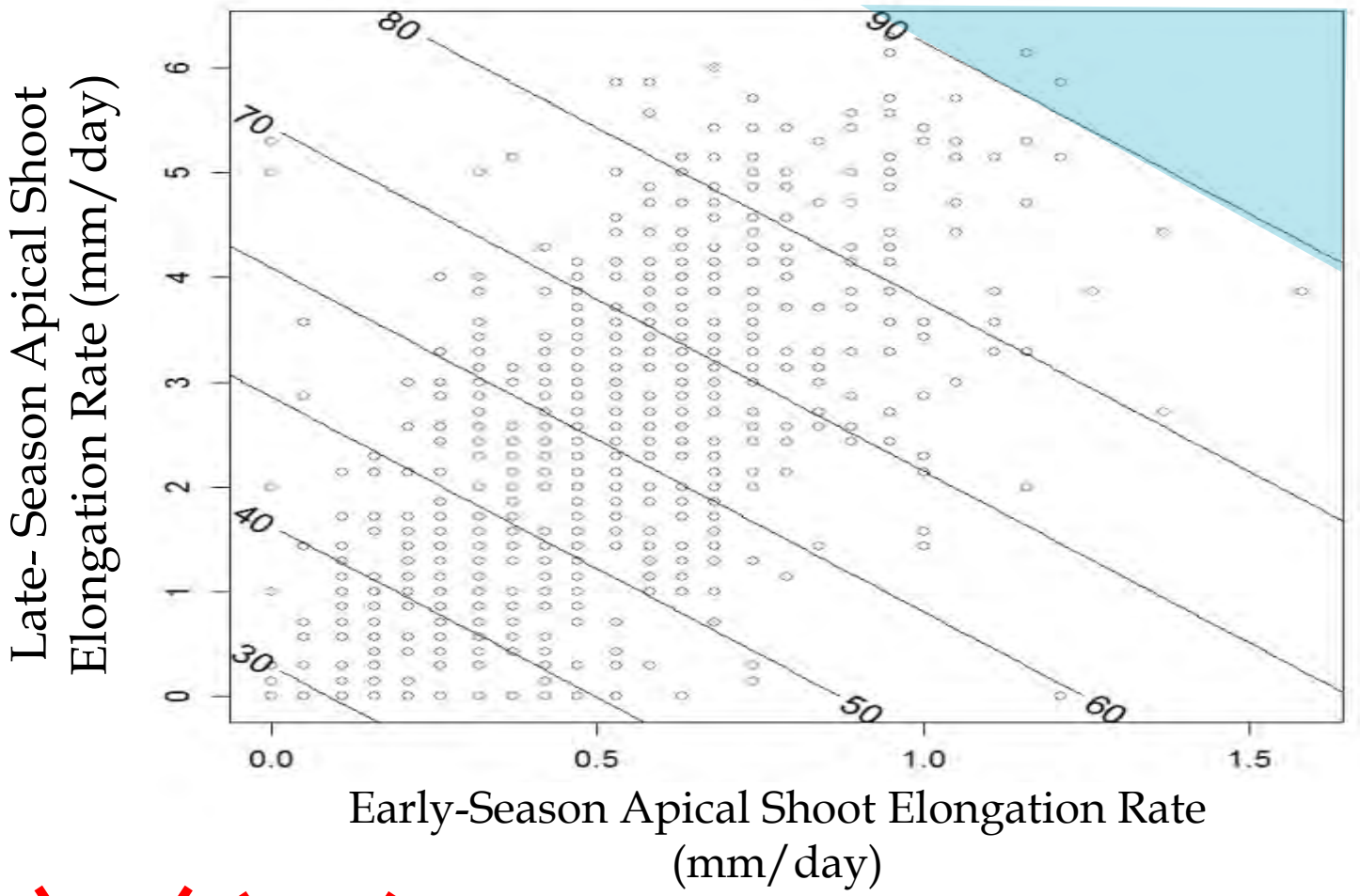
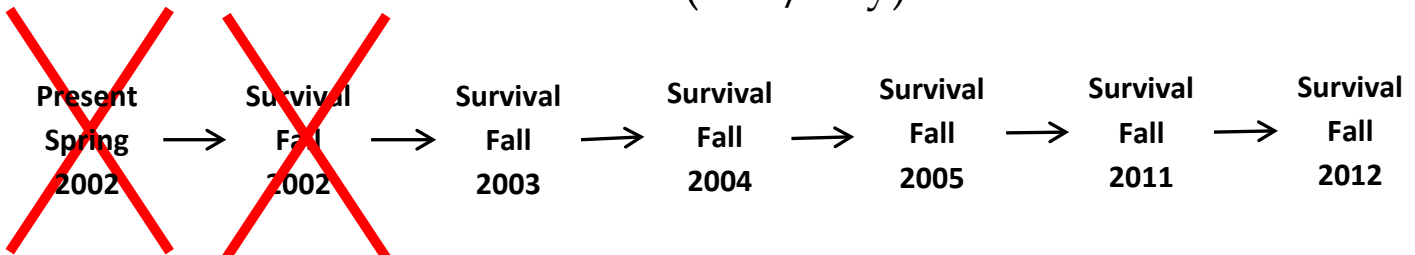
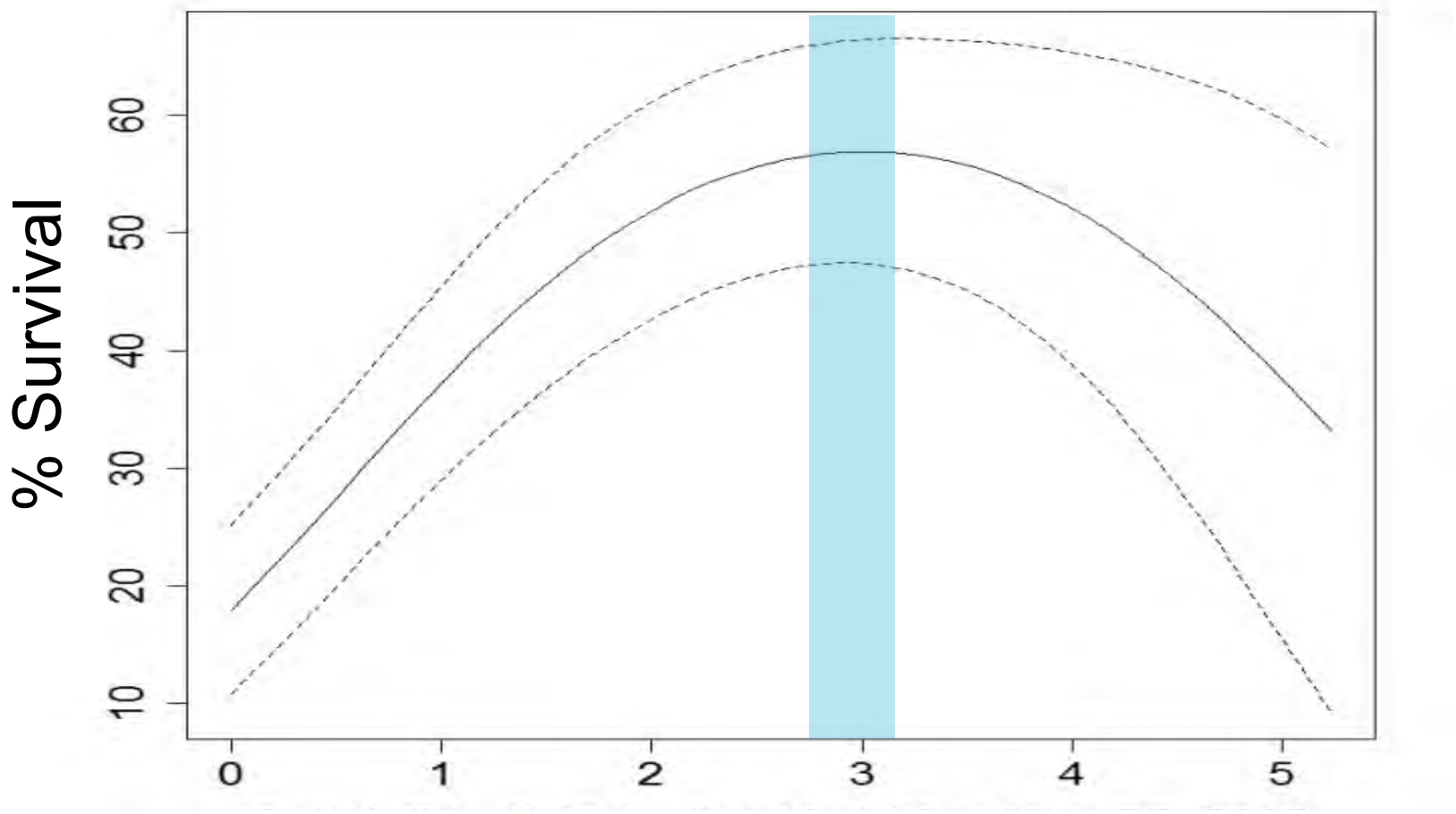
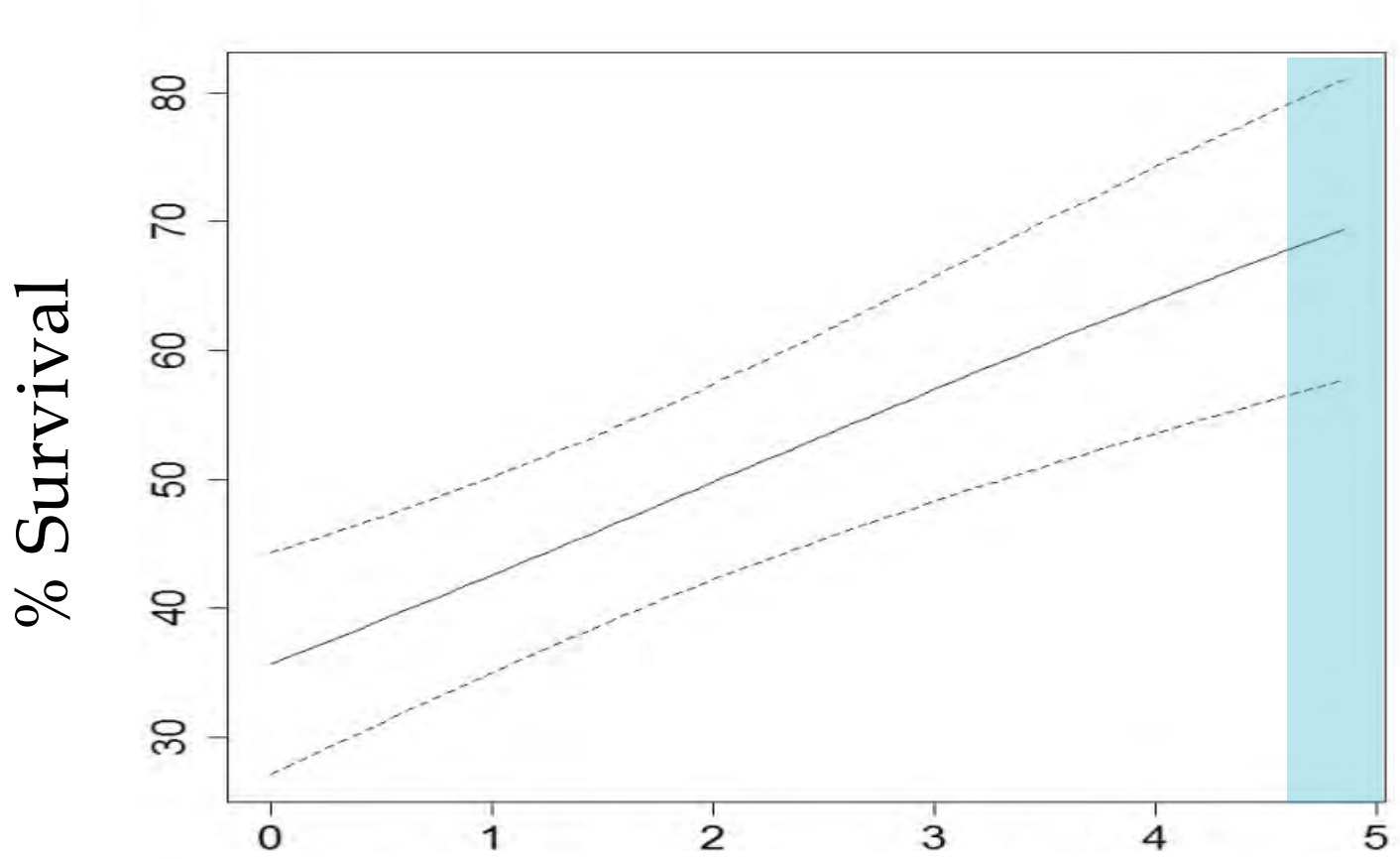


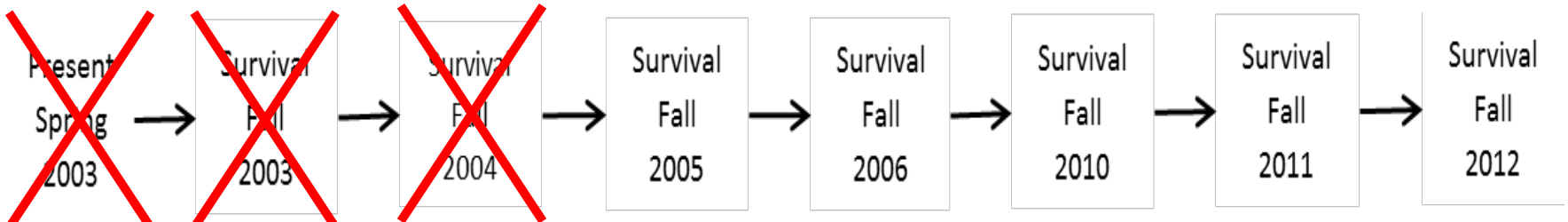


Experiment 2: Fitness Surface (% Survival 2003-2012) for Shoot Elongations Rate in 2003

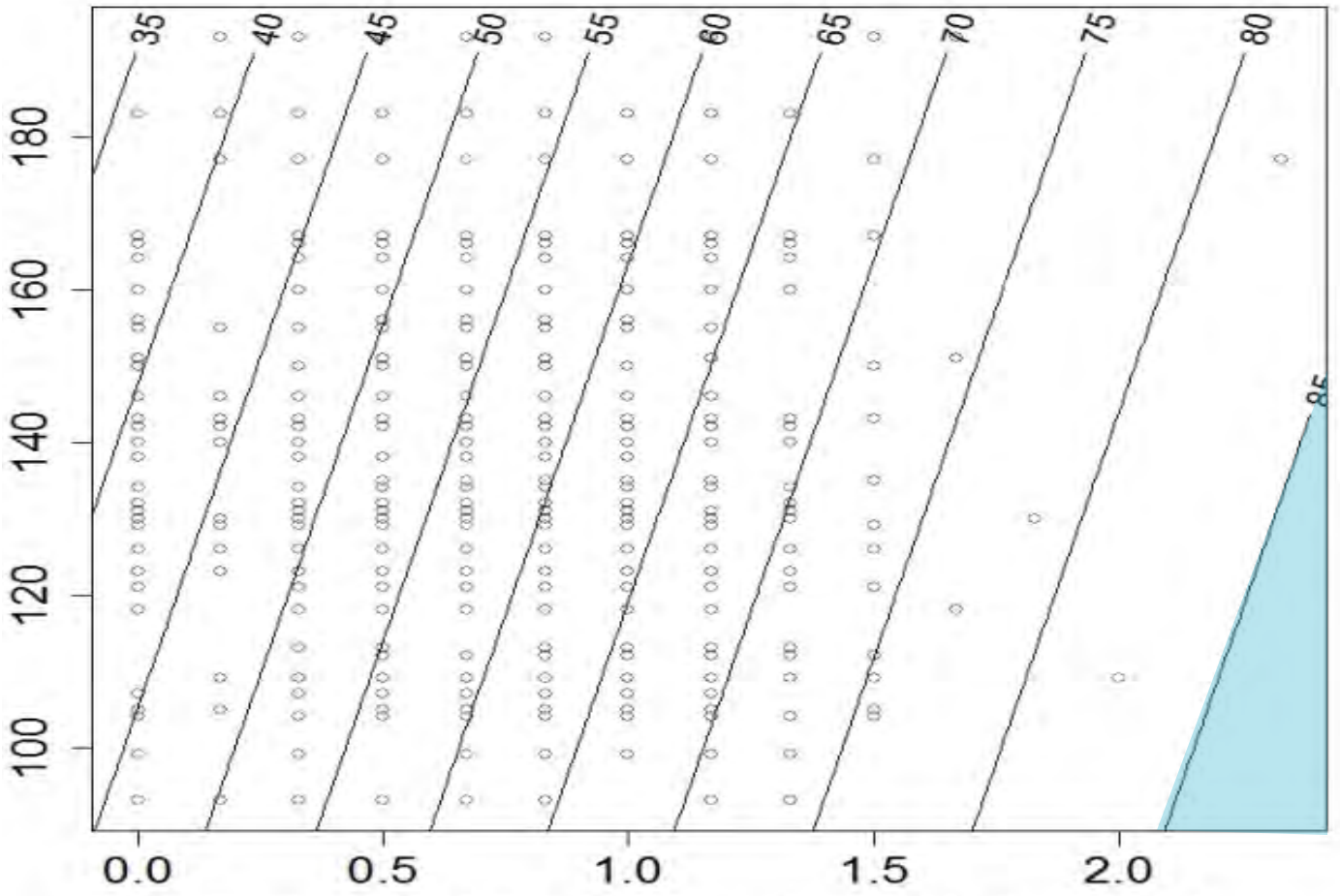


Experiment 2: Fitness Surface (% Survival 2005-2012) for Shoot Elongation Rate in 2003





Experiment 2: Fitness Surface (% Survival 2007-2012)



38% mortality In 2006

Chapter 2: Summary Key Results

- Moderate disruptive selection in Exp. 1 and stabilizing selection in Exp. 2 was detected
- Differential mortality and not differential height growth among survivors was the principal driver of selection
- Disruptive and stabilizing selection resulted from differential mortality only in the earliest years.
- Selection on growth rhythm appeared to be independent of selection on traits associated with drought tolerance

Future Research

- What is the tempo and form of phenotypic selection on growth rhythm in native habitat ?

Photo by: unkown

Acknowledgements

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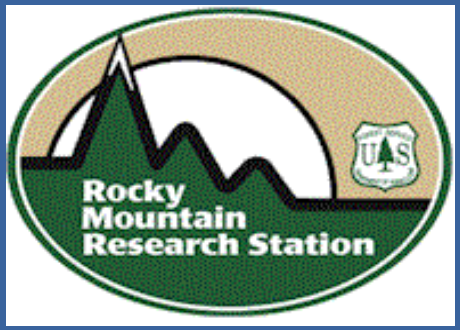
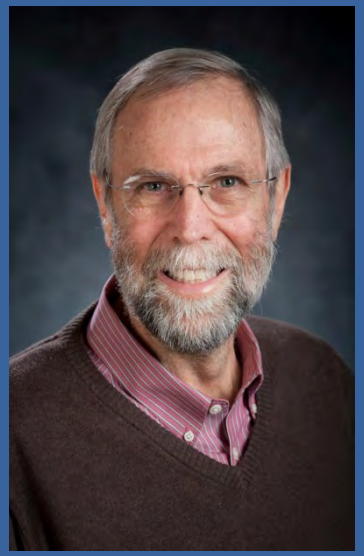
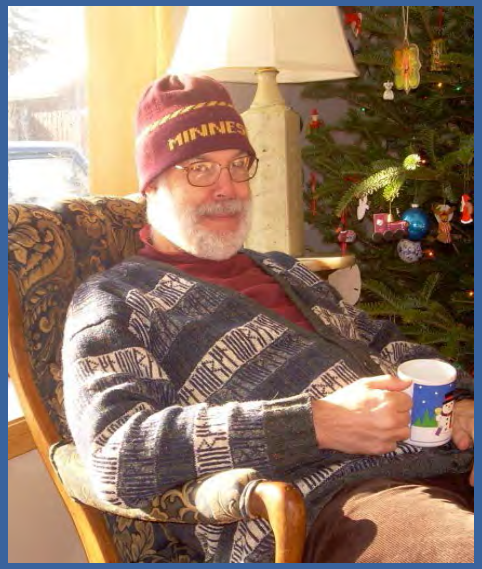


Gerald Rehfeldt



Nicholas Crookston

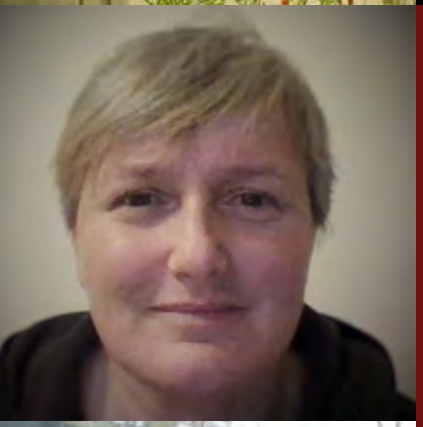
Ned Klopfenstein



Charles Geyer

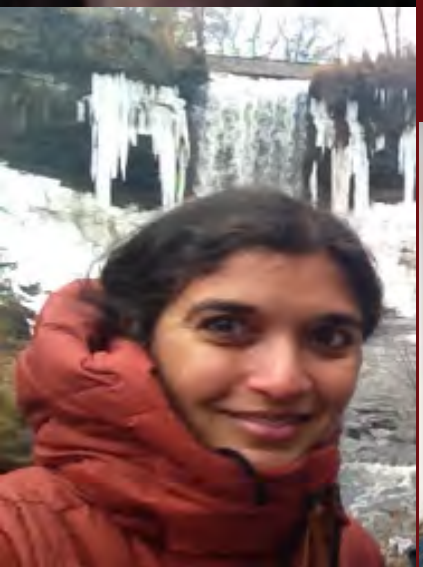




Shaw Research Lab Group

Past and Present



Whitebark Seed Collections

Response Variables