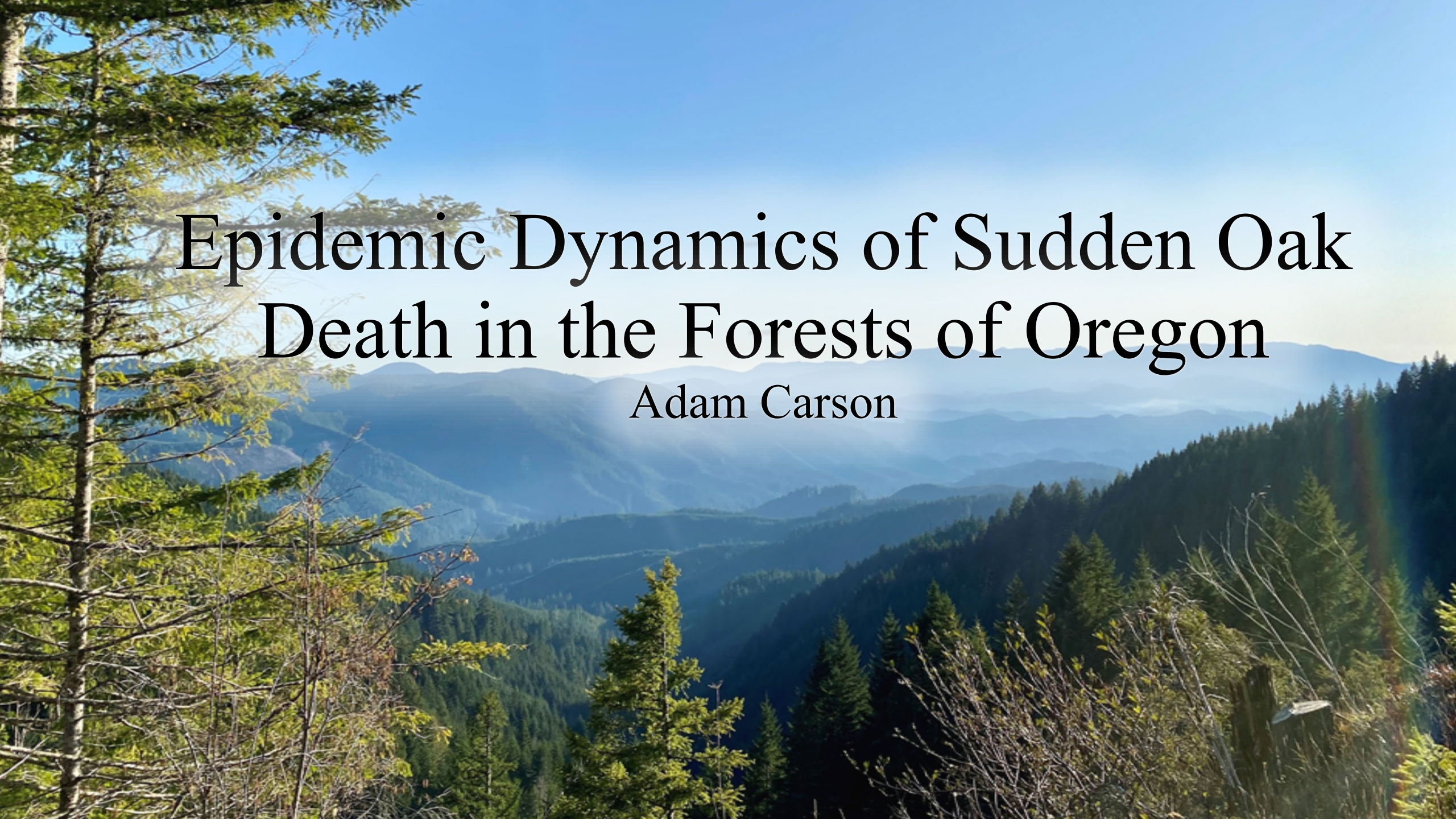


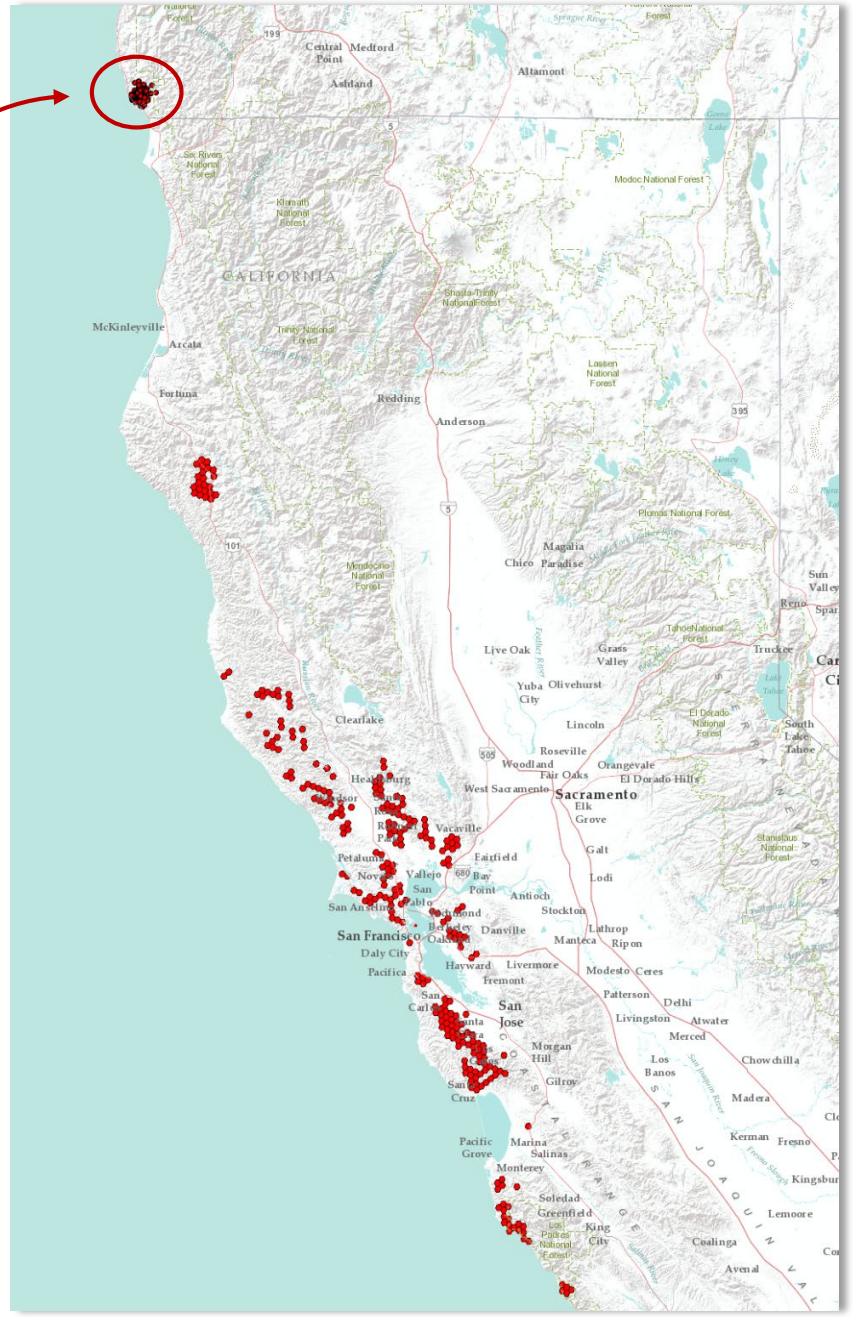
Epidemic Dynamics of Sudden Oak Death in the Forests of Oregon

Adam Carson

Introduction

P. ramorum background:

- Oomycete pathogen (water mold)
- Causal agent of Sudden Oak Death (SOD)
- Exotic introduction to the U.S. mid 1990's
  - Wide distribution in California
  - In Oregon, range is restricted to Curry County
  - 42.8 million disease-killed trees in CA & OR by 2019 (Cobb, Richard C., et al. 2020)
- Four clonal lineages:
  - NA1, NA2, EU1, EU2
- Generalist pathogen:
  - Can infect over 130 species of plants
  - In Oregon primary host is tanoak



Map curtesy of: Oregon Dept. Forestry, Maggie Kelly Lab, UC Berkeley

Introduction

Photo: Ebba Peterson

Photo : Jared LeBoldus

Introduction

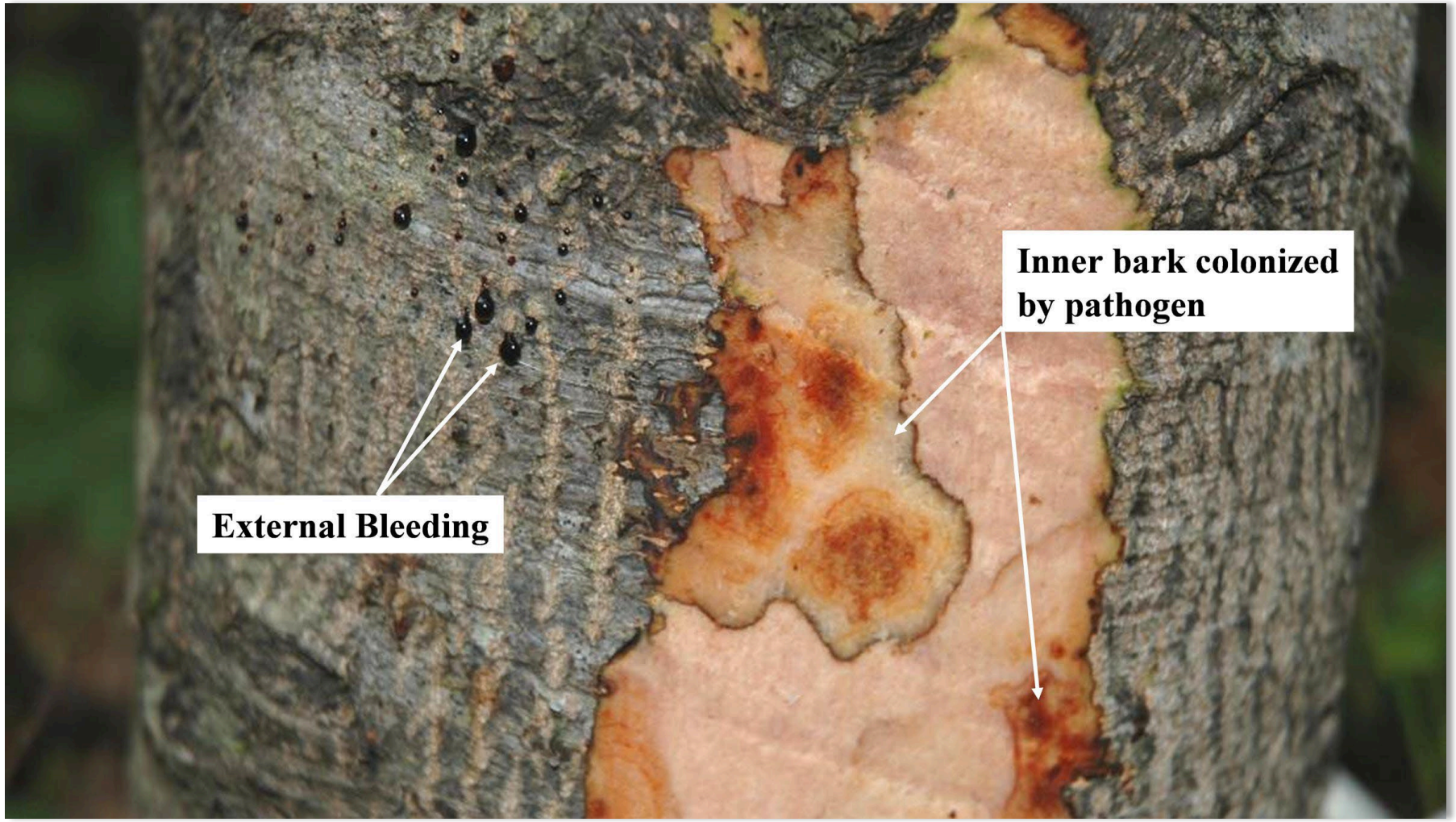
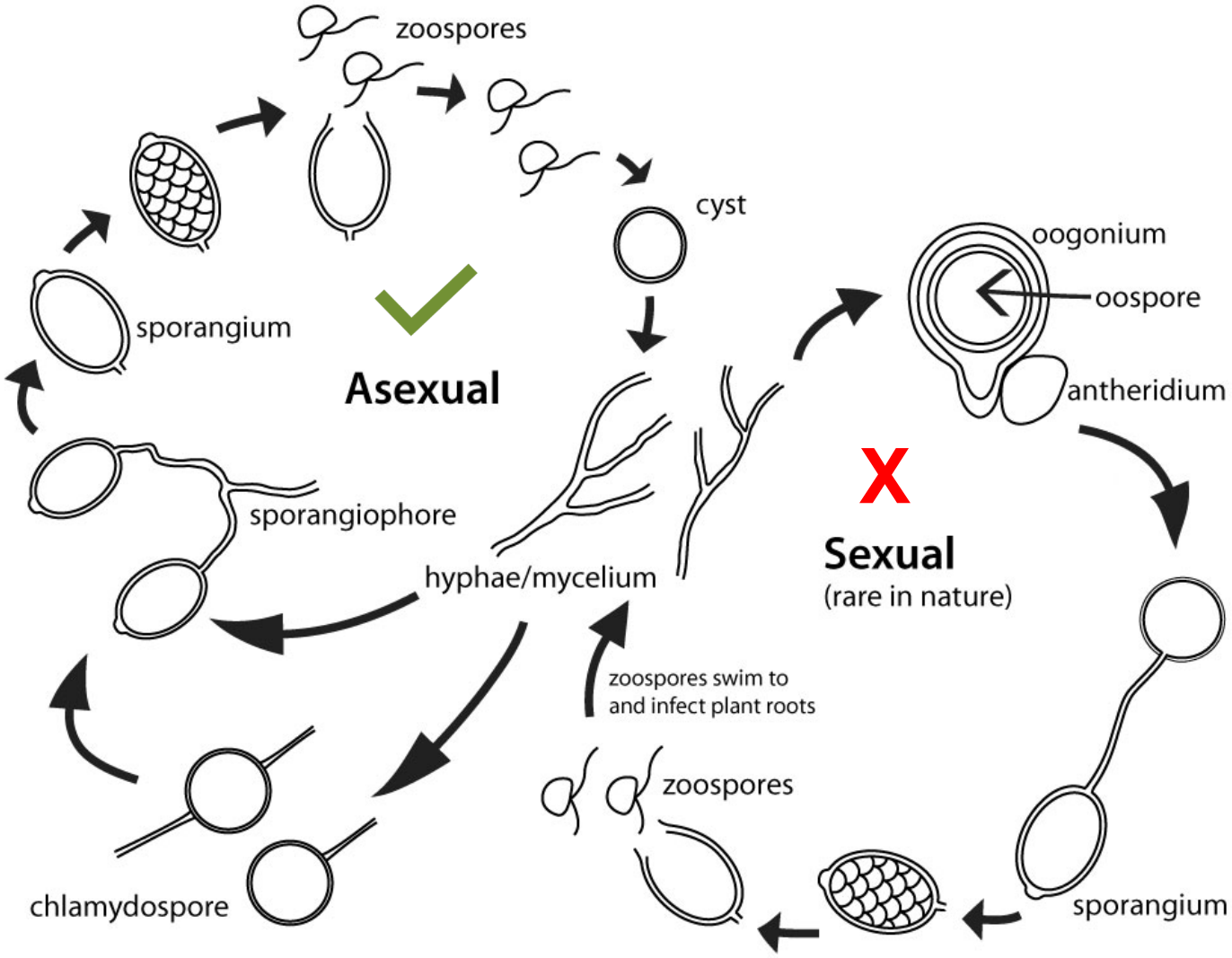


Photo: Robbie Flowers

Introduction

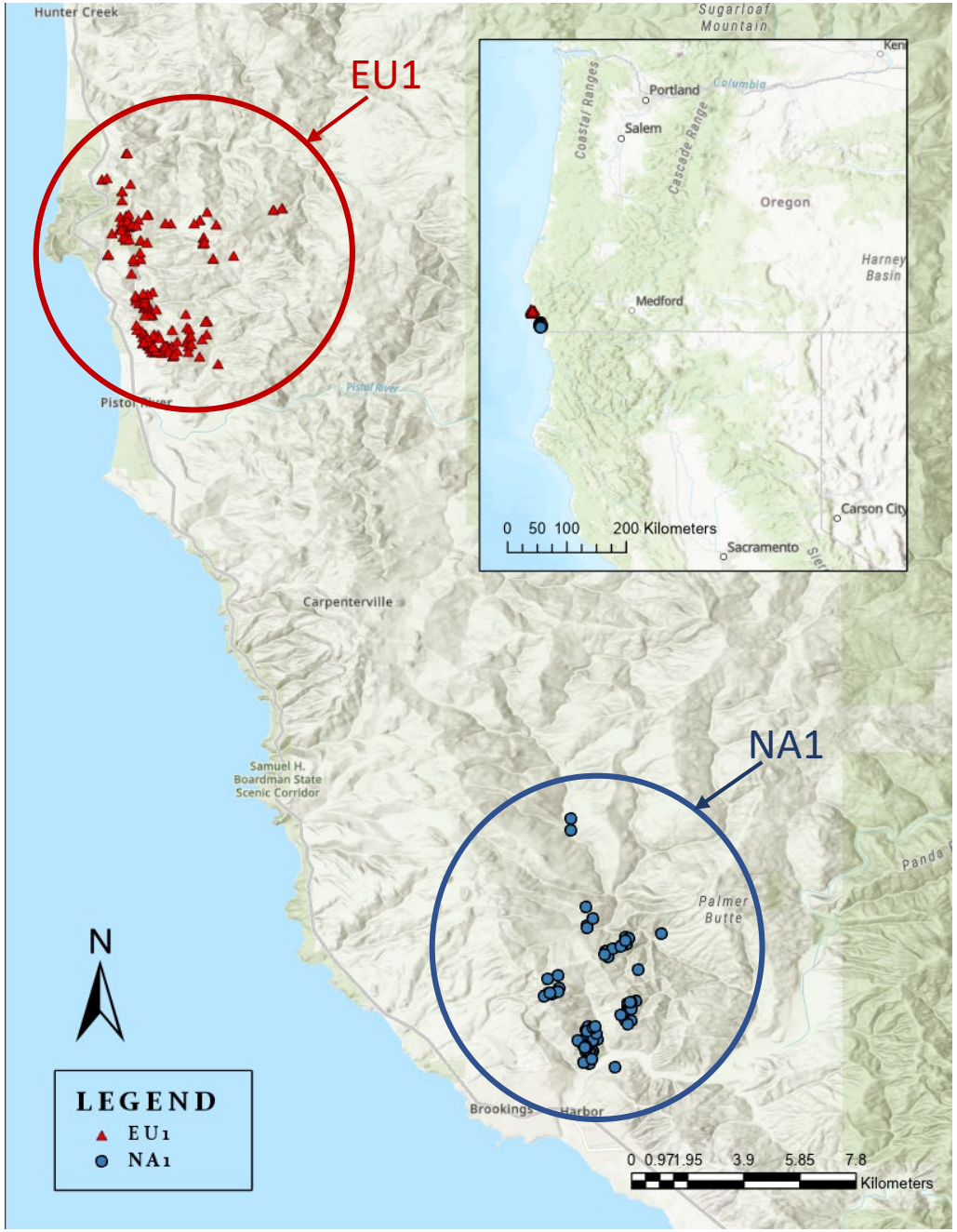
Introduction



Materials & Methods

Isolate Selection:

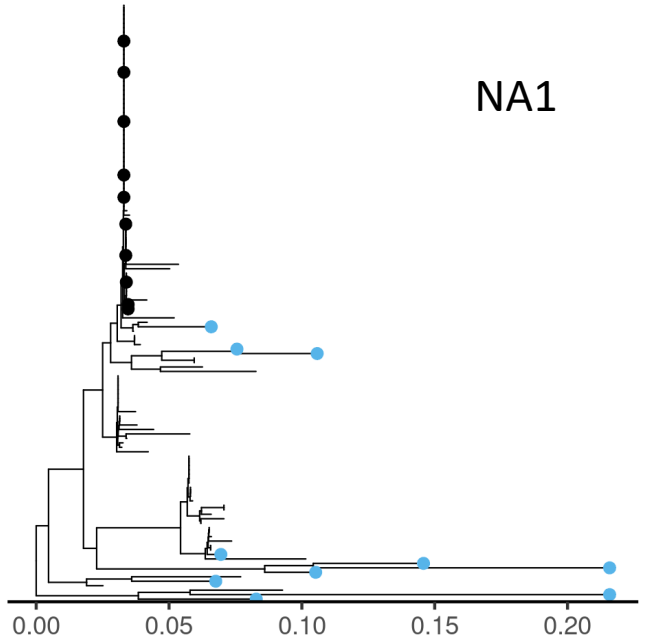
- Isolates collected by Oregon Department of Forestry from the NA1 & EU1 epidemic area in Curry County
- Isolates collected by Oregon Department of Forestry from the NA1 & EU1 epidemic area in Curry County
- NA1 collected 2001-2005
- EU1 collected 2015-2019
- Lineages geographically separated

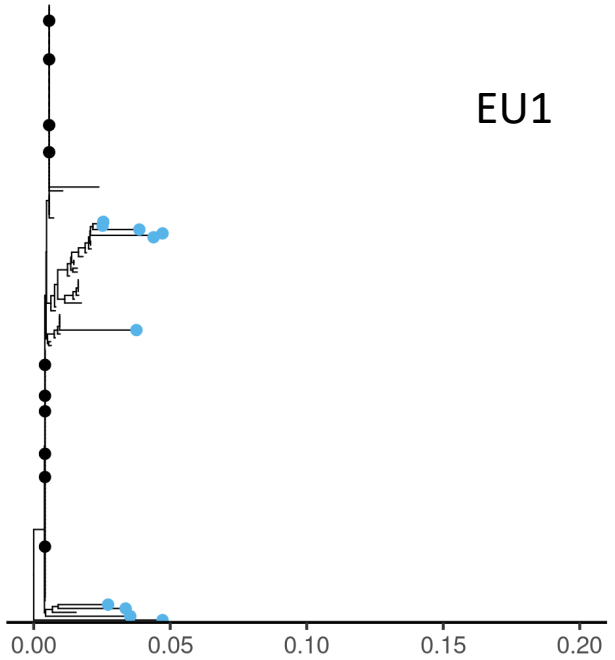


Materials & Methods

Isolate Selection:

- 300 fully-sequenced isolates (EU1 & NA1) from the first five years of the Oregon SOD outbreaks
- SNP data used to generate BUSCO neighbor joining trees for each lineage

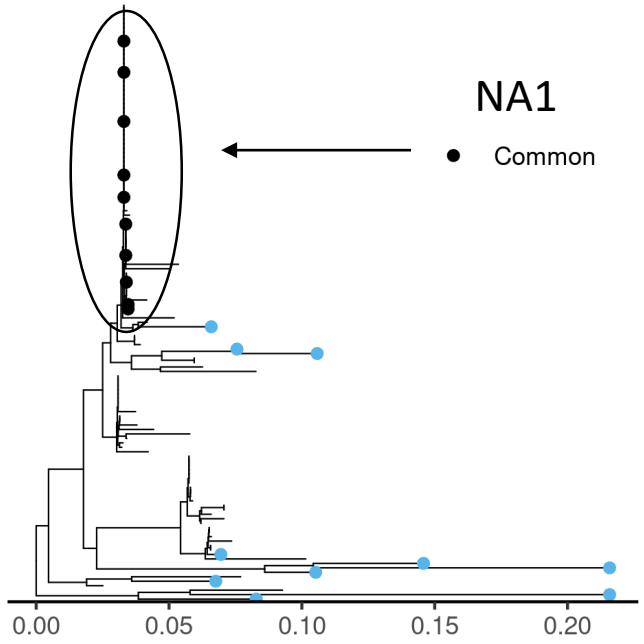


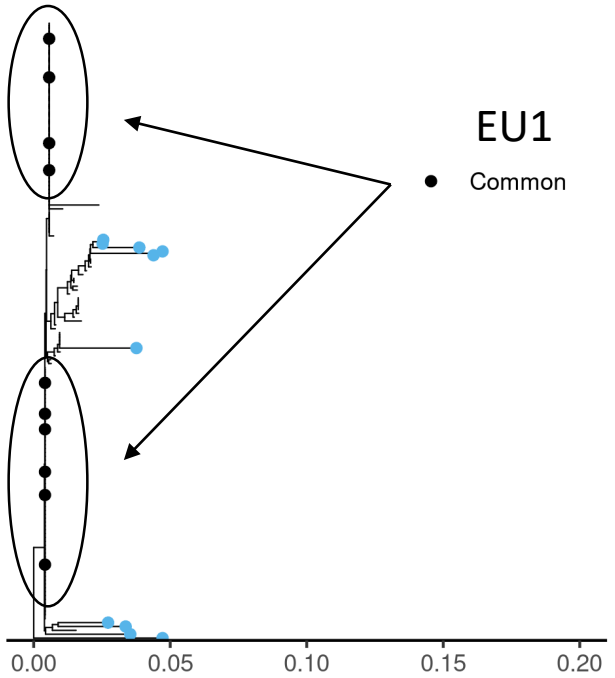


Materials & Methods

Isolate Selection:

- 300 fully-sequenced isolates (EU1 & NA1) from the first five years of the Oregon SOD outbreaks
- SNP data used to generate BUSCO neighbor joining trees for each lineage
- Highly represented clades considered ‘common’ (abundant)

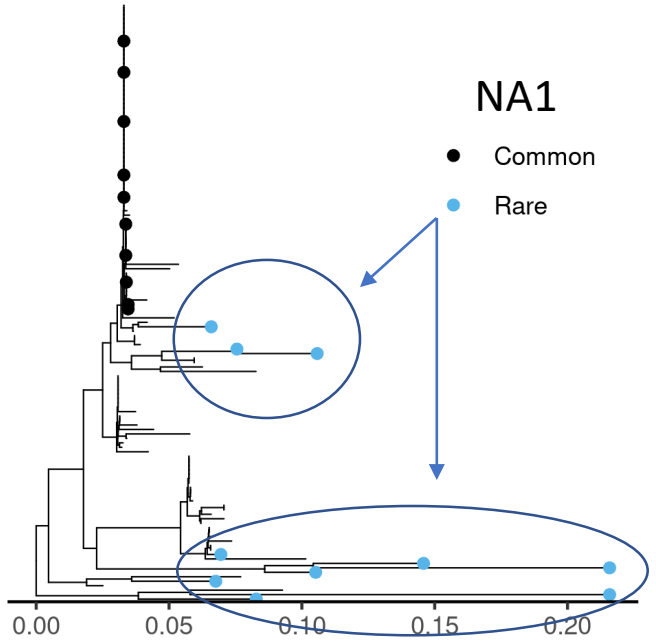


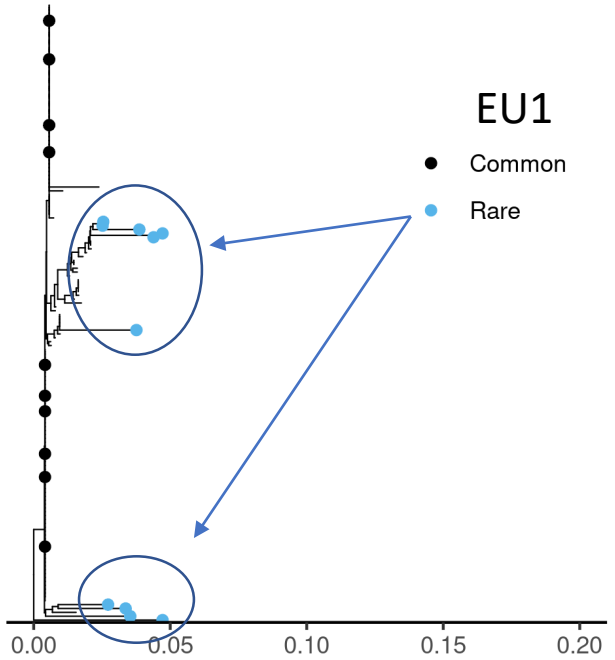


Materials & Methods

Isolate Selection:

- 300 fully-sequenced isolates (EU1 & NA1) from the first five years of the Oregon SOD outbreaks
- SNP data used to generate BUSCO neighbor joining trees for each lineage
- Highly represented clades considered ‘common’ (abundant)
- Less represented clades considered ‘rare’ (less-abundant)

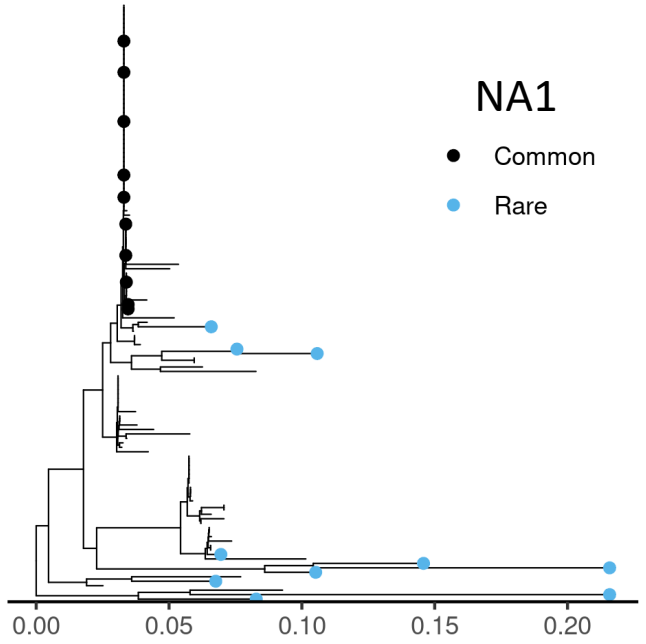


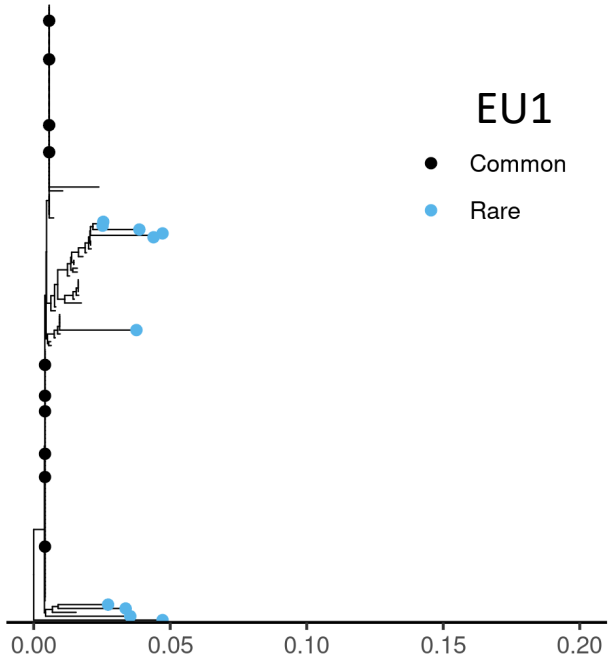


Materials & Methods

Isolate Selection:

- 300 fully-sequenced isolates (EU1 & NA1) from the first five years of the Oregon SOD outbreaks
- SNP data used to generate BUSCO neighbor joining trees for each lineage
- Highly represented clades considered ‘common’ (abundant)
- Less represented clades considered ‘rare’ (less-abundant)
- 40 isolates selected (10 common & 10 rare for each lineage)
- Common isolates selected randomly, rare isolates selected by greatest genetic distance

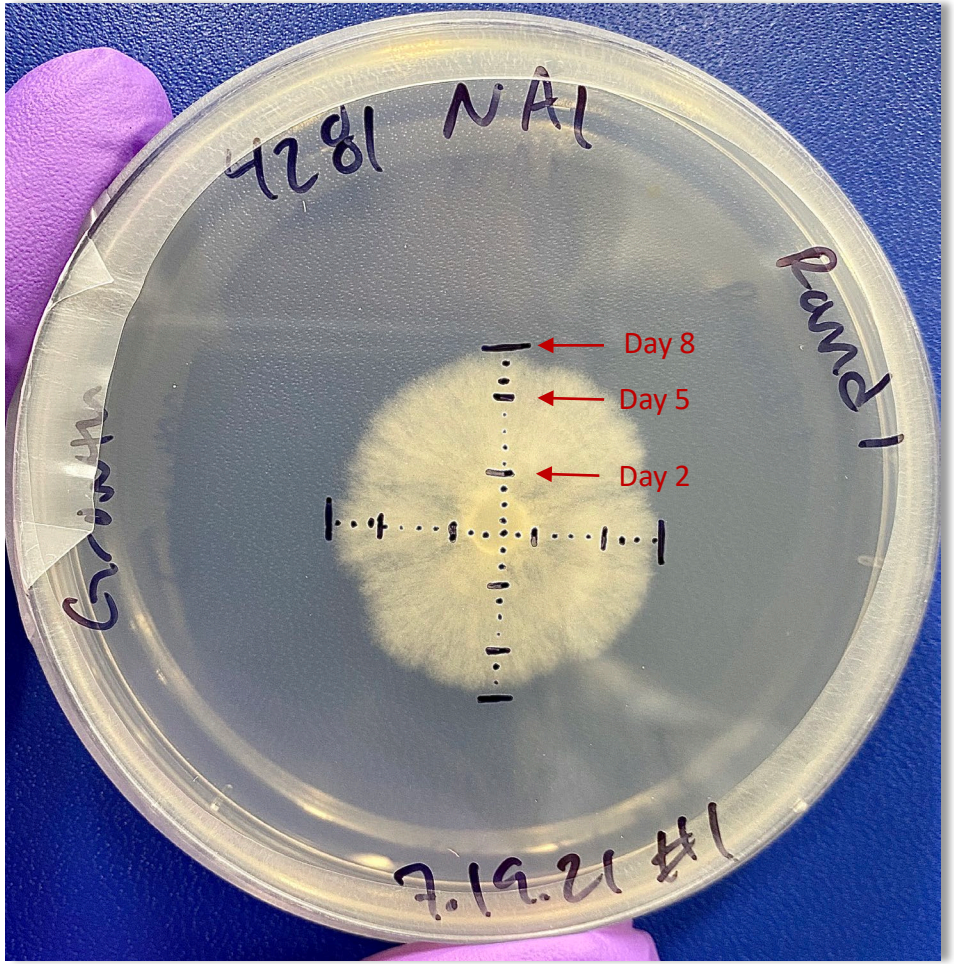




Materials & Methods

Isolate Growth Measurements:

- Plate isolates on artificial growth media
- Growth expansion tracked along 4 perpendicular radii
  - Edge of growth marked on day 2, day 5, day 8
- Measurements used to calculate:
  - Growth rate (mm/day)
  - Final area of growth (mm^2)



Materials & Methods

Leaf Inoculations:

- Cultured isolates used to wound-inoculate tanoak leaves
- 2 week incubation at 6°C, 11°C, & 16°C

Materials & Methods

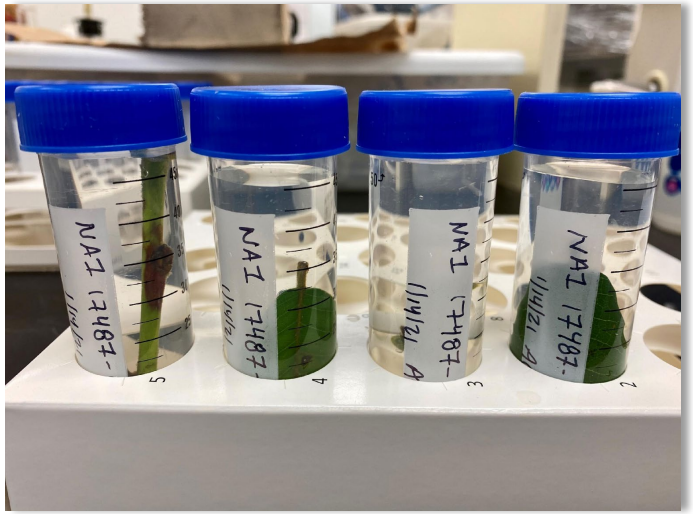
Leaf Inoculations:

- Cultured isolates used to wound-inoculate tanoak leaves
- 2 week incubation at 6°C, 11°C, & 16°C

Materials & Methods

Leaf Inoculations:

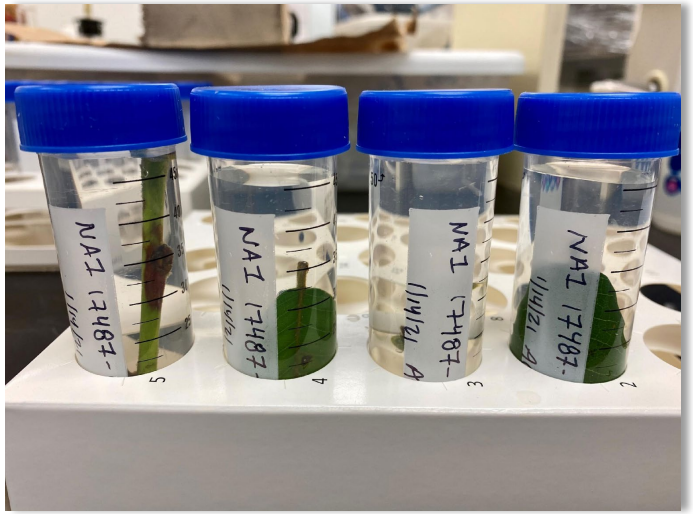
- Cultured isolates used to wound-inoculate tanoak leaves
- 2 week incubation at 6°C, 11°C, & 16°C
- Sporangia captured via vacuum filtration

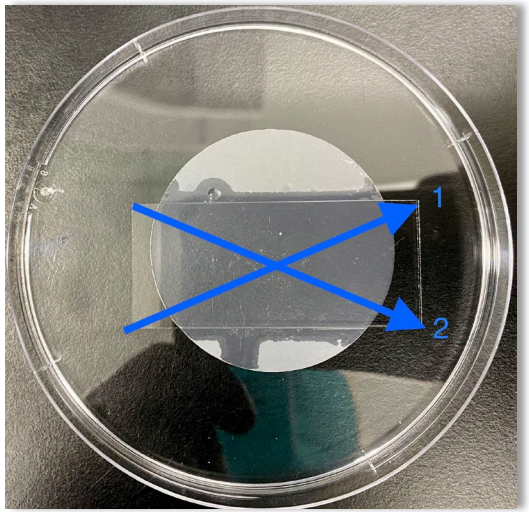


Materials & Methods

Leaf Inoculations:

- Cultured isolates used to wound-inoculate tanoak leaves
- 2 week incubation at 6°C, 11°C, & 16°C
- Sporangia captured via vacuum filtration
- Sporangia counted along 2 diagonal transects

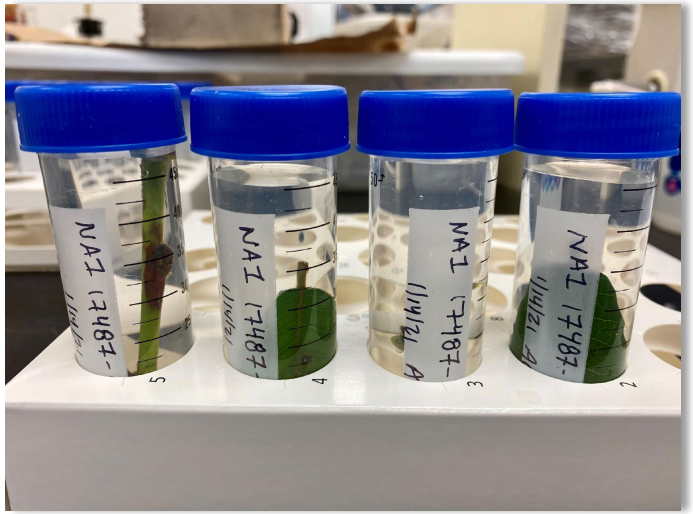


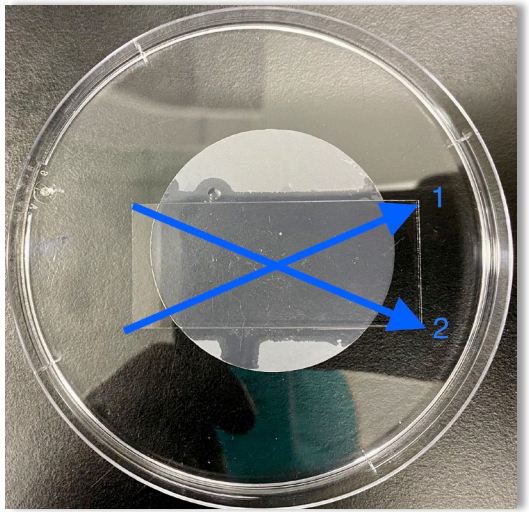


Materials & Methods

Leaf Inoculations:

- Cultured isolates used to wound-inoculate tanoak leaves
- 2 week incubation at 6°C, 11°C, & 16°C
- Sporangia captured via vacuum filtration
- Sporangia counted along 2 diagonal transects

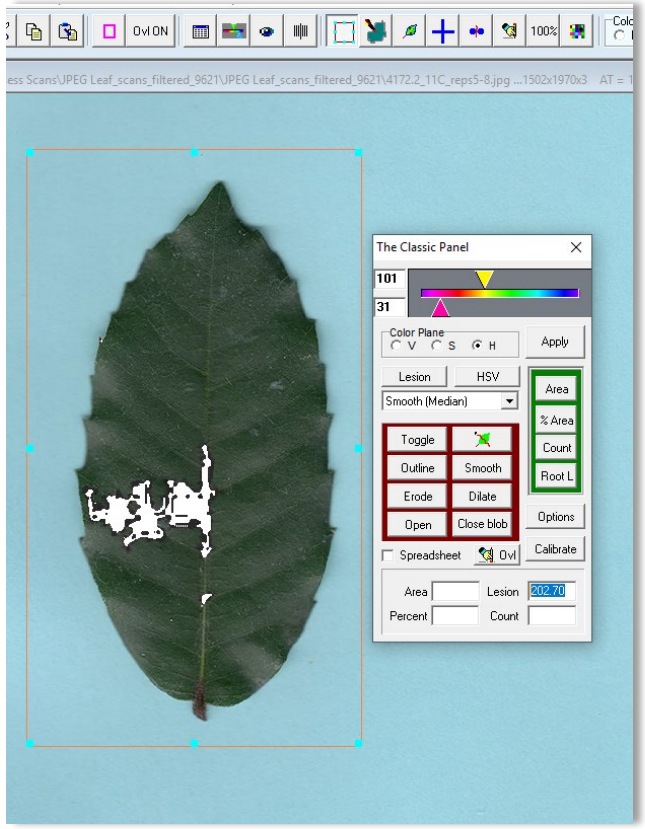




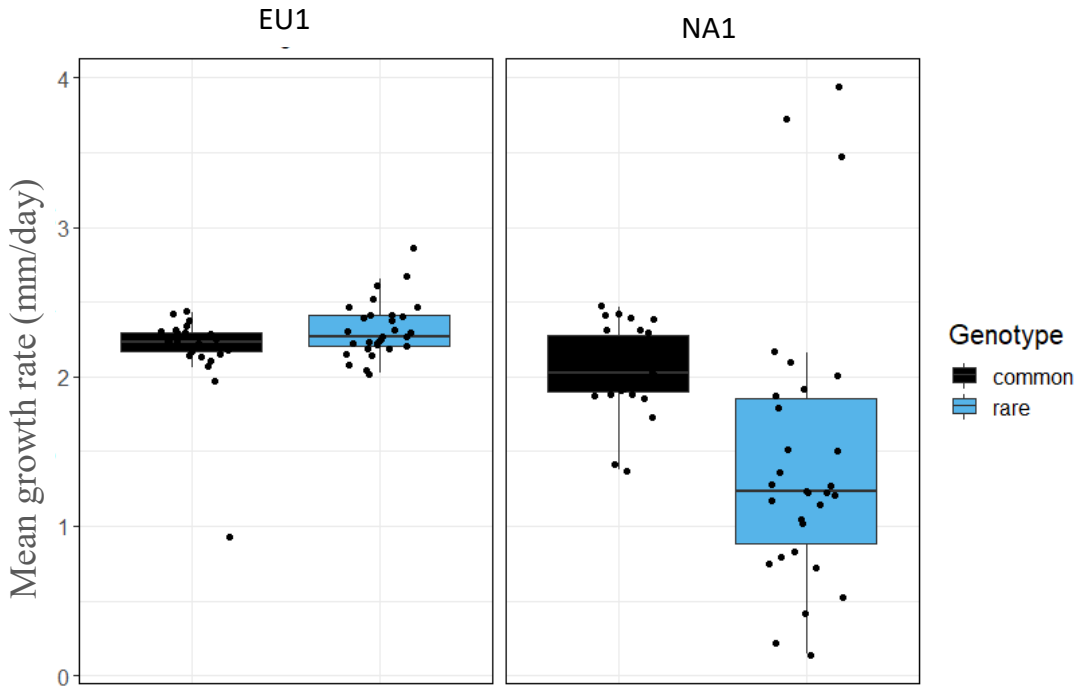
Materials & Methods

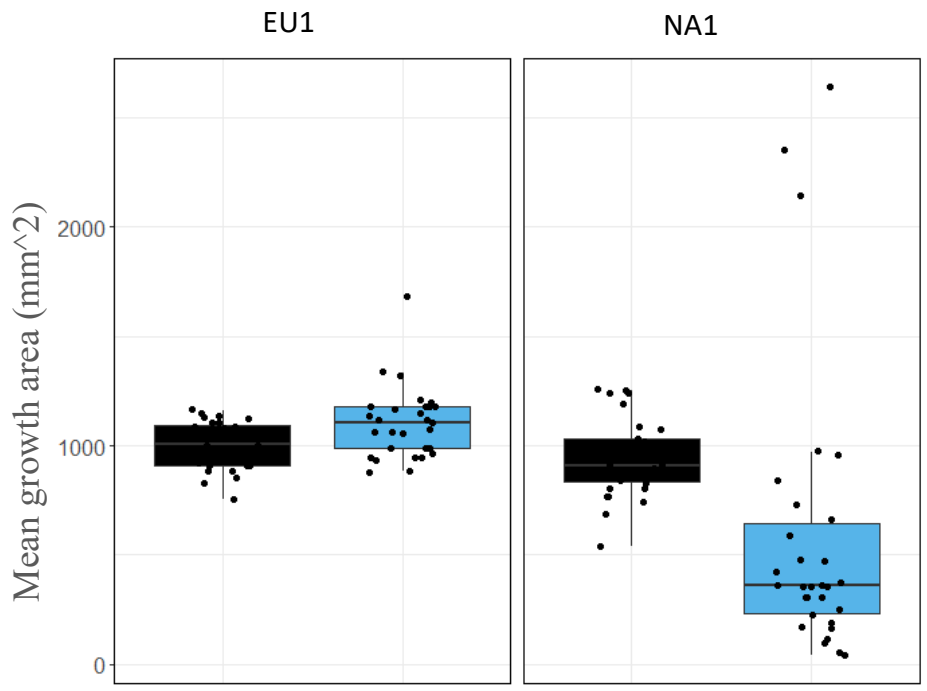
Lesion Measurements:

- Inoculated leaves scanned for lesion measuring, post sporangia capture
- Leaf & lesion area quantified using APS ASSESS 2.0 software
- Measurements used to calculate proportion of leaf-lesion area

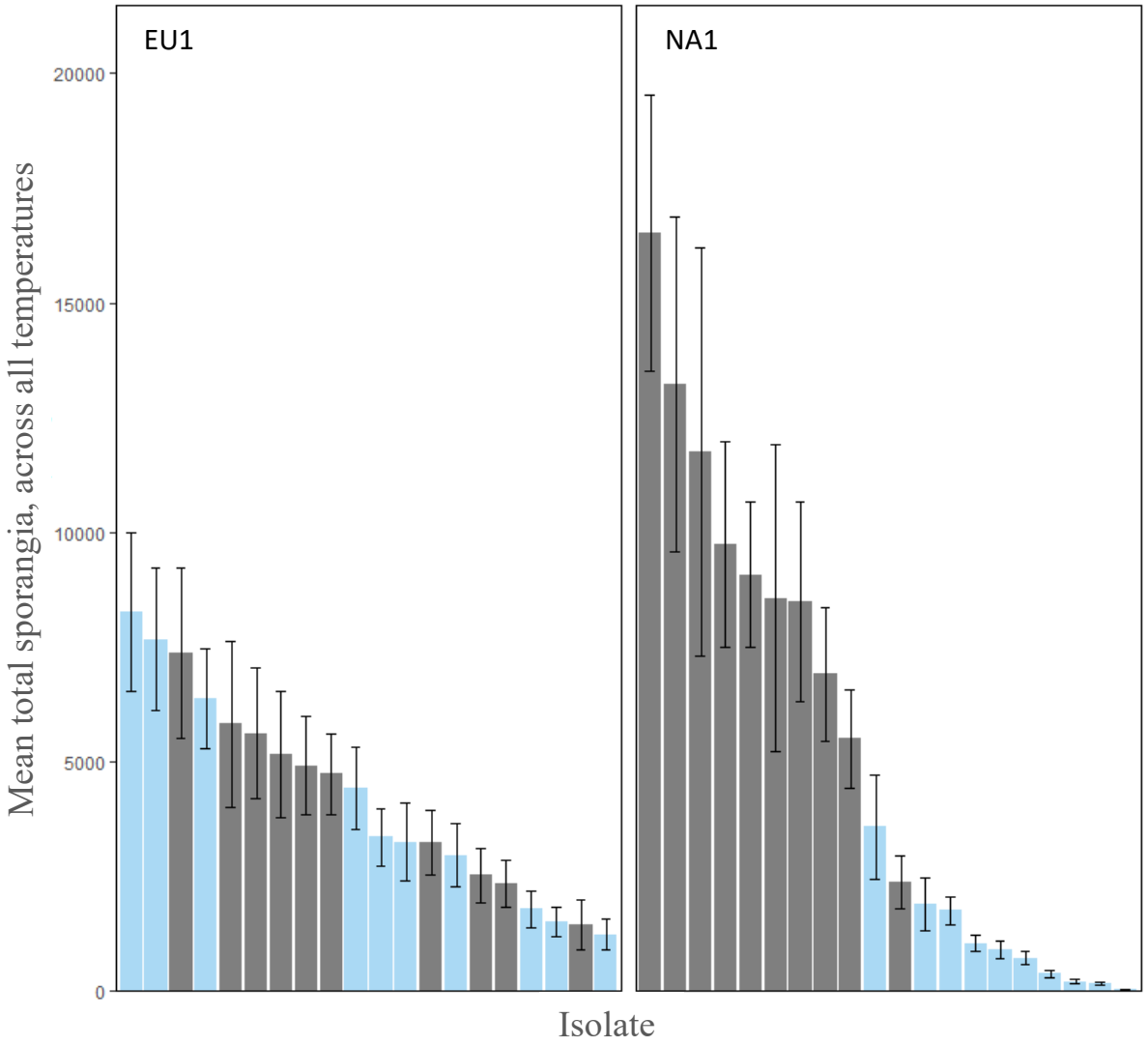


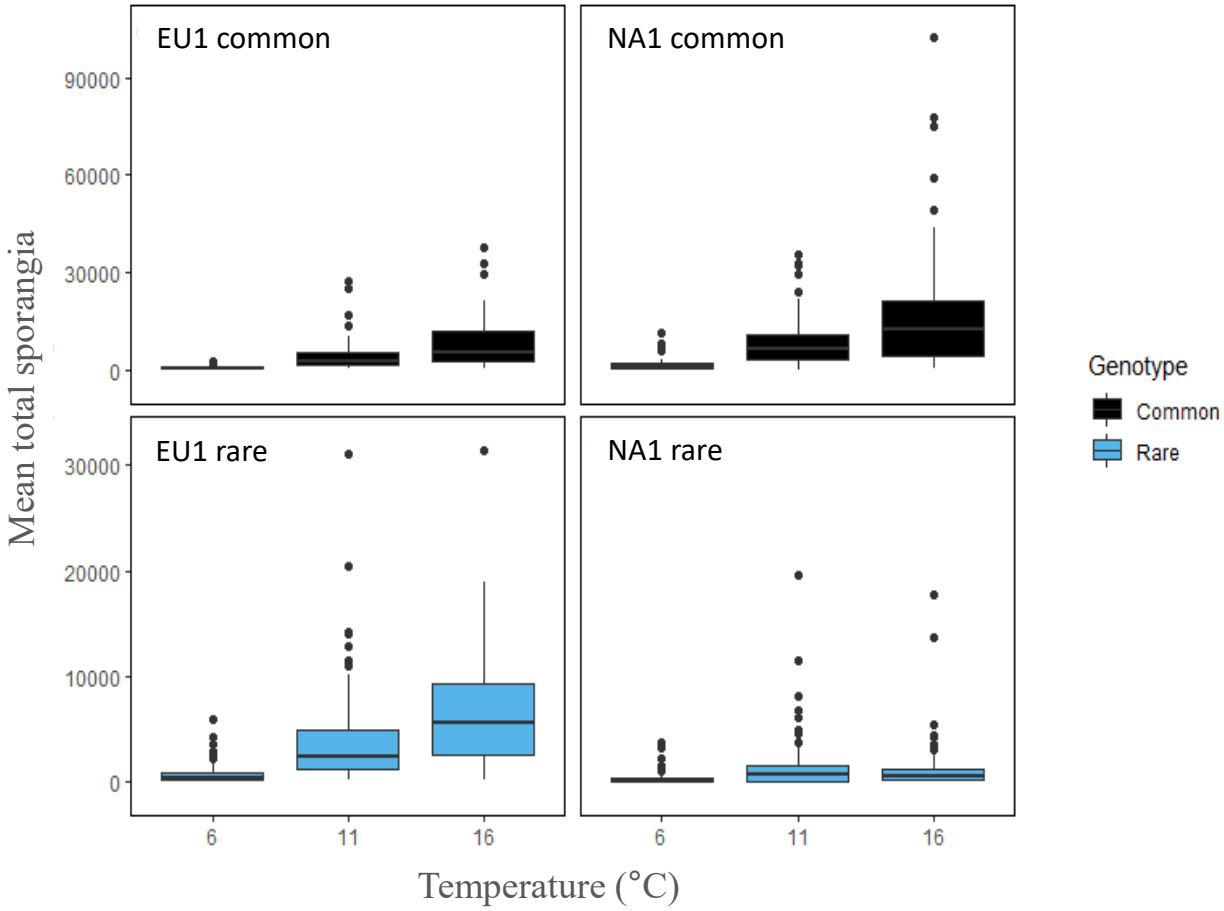
Results


EU1
NA1
Mean growth rate (mm/day)
0
1
2
3
4
Genotype
common
rare

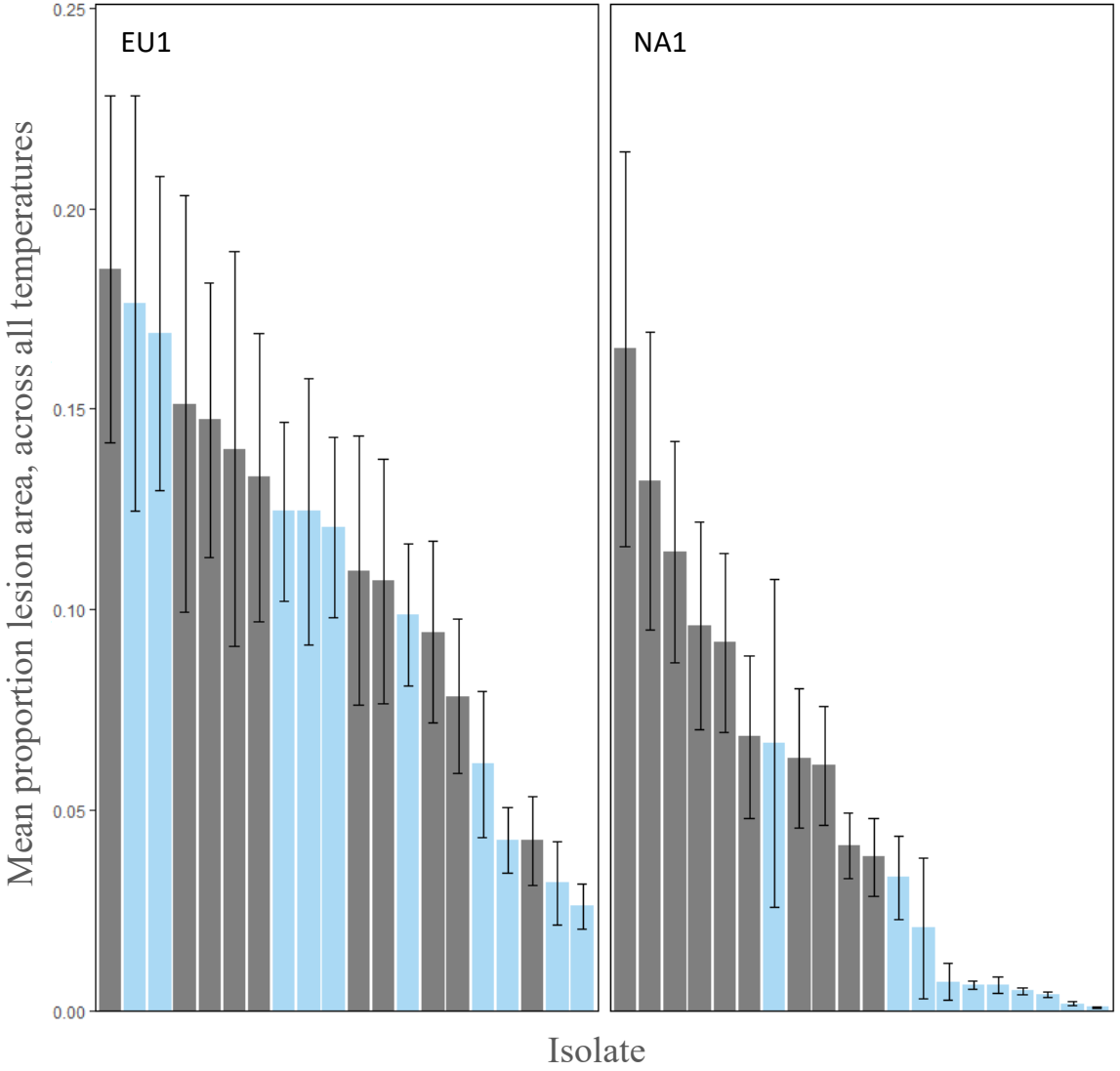

EU1
NA1
Mean growth area (mm^2)
0
1000
2000

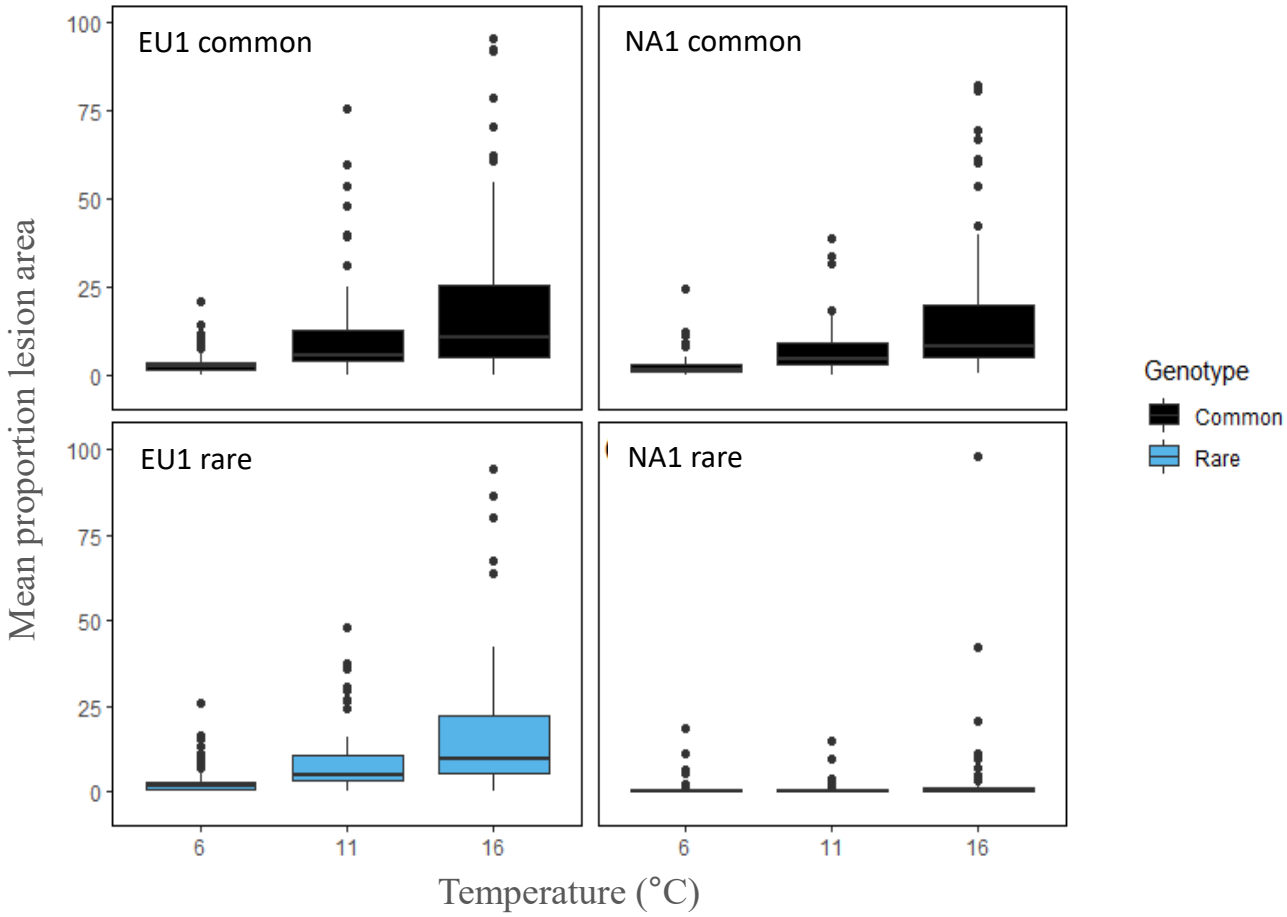
Results


EU1
NA1
20000
15000
10000
5000
0
Mean total sporangia, across all temperatures
Isolate


EU1 common
NA1 common
EU1 rare
NA1 rare
90000
60000
30000
0
30000
20000
10000
0
6
11
16
Mean total sporangia
Temperature (°C)
Genotype
Common
Rare

Results


EU1
NA1
Mean proportion lesion area, across all temperatures
0.25
0.20
0.15
0.10
0.05
0.00
Isolate


EU1 common
NA1 common
EU1 rare
NA1 rare
Mean proportion lesion area
100
75
50
25
0
6
11
16
Temperature (°C)
Genotype
Common
Rare

Introduction

SOD Disease management:

- Local eradication of infected tanoak trees
- Aerial surveys for detection of infected trees

Introduction

SOD Disease management:

- Local eradication of infected tanoak trees
- Aerial surveys for detection of infected trees
- Treatment buffers established
- ‘Hack-and-squirt’ herbicide application of all tanoaks within the treatment boundaries

Introduction

SOD Disease management:

- Local eradication of infected tanoak trees
- Aerial surveys for detection of infected trees
- Treatment buffers established
- ‘Hack-and-squirt’ herbicide application of all tanoaks within the treatment boundaries
- Felling and burning of all tanoaks within treatment boundaries

Introduction

Table 2. Funding sources and total costs (in US$) for management of the sudden oak death epidemic in southwestern Oregon forests[a]

Year	USFS (Federal)	ODF (State)	BLM (Federal)	Landowners (Private)	Other agencies (State)	USDA APHIS/NRCS (Federal)	USFS ARRA (Federal)	Total program funding
2001	96,100	25,000	–	–	–	–	–	121,100
2002	258,400	50,000	–	–	–	–	–	308,400
2003	222,000	70,000	–	10,000	–	–	–	302,000
2004	404,700	70,000	–	10,000	–	–	–	484,700
2005	130,000	70,000	–	10,000	–	–	–	210,000
2006	424,000	436,000	–	10,000	–	70,000	–	940,000
2007	530,000	814,000	25,000	10,000	–	75,000	–	1,454,000
2008	838,000	252,000	445,000	10,000	–	325,000	–	1,870,000
2009	359,200	150,000	700,000	10,000	–	–	–	1,219,200
2010	569,000	95,000	531,000	10,000	–	–	2,692,000	3,897,000
2011	735,000	175,000	507,000	207,000	86,500	–	–	1,710,500
2012	805,000	260,000	447,000	-	–	–	–	1,512,000
2013	577,300	395,000	239,000	10,000	–	–	10,000	1,231,300
2014	640,000	290,000	557,000	10,000	10,000	–	–	1,507,000
2015	915,000	290,000	450,000	15,000	–	20,000	–	1,690,000
2016	842,000	490,000	467,000	10,000	–	20,000	–	1,829,000
2017	913,500	942,000	489,000	10,000	81,000	–	–	2,435,500
2018	1,188,997	1,215,000	328,784	10,000	334,687	–	–	3,077,468
2019	870,000	1,915,000	458,749	10,000	–	397,490	–	3,651,239
2020	1,138,000	365,000	737,000	10,000	15,774	116,711	–	2,382,485
2021	875,000	1,915,000	279,091	10,000	–	–	–	3,079,091
Total	13,331,197	10,284,000	6,660,624	382,000	527,961	1,024,201	2,702,000	34,911,983

[a] USFS = United States Forest Service, ODF = Oregon Department of Forestry, BLM = Bureau of Land Management, Other agencies = Other Oregon state agencies, USDA = United States Department of Agriculture, APHIS = Animal and Plant Health Inspection Service, NRCS = Natural Resources Conservation Service, and ARRA = Americans for Responsible Recreational Access.

Introduction

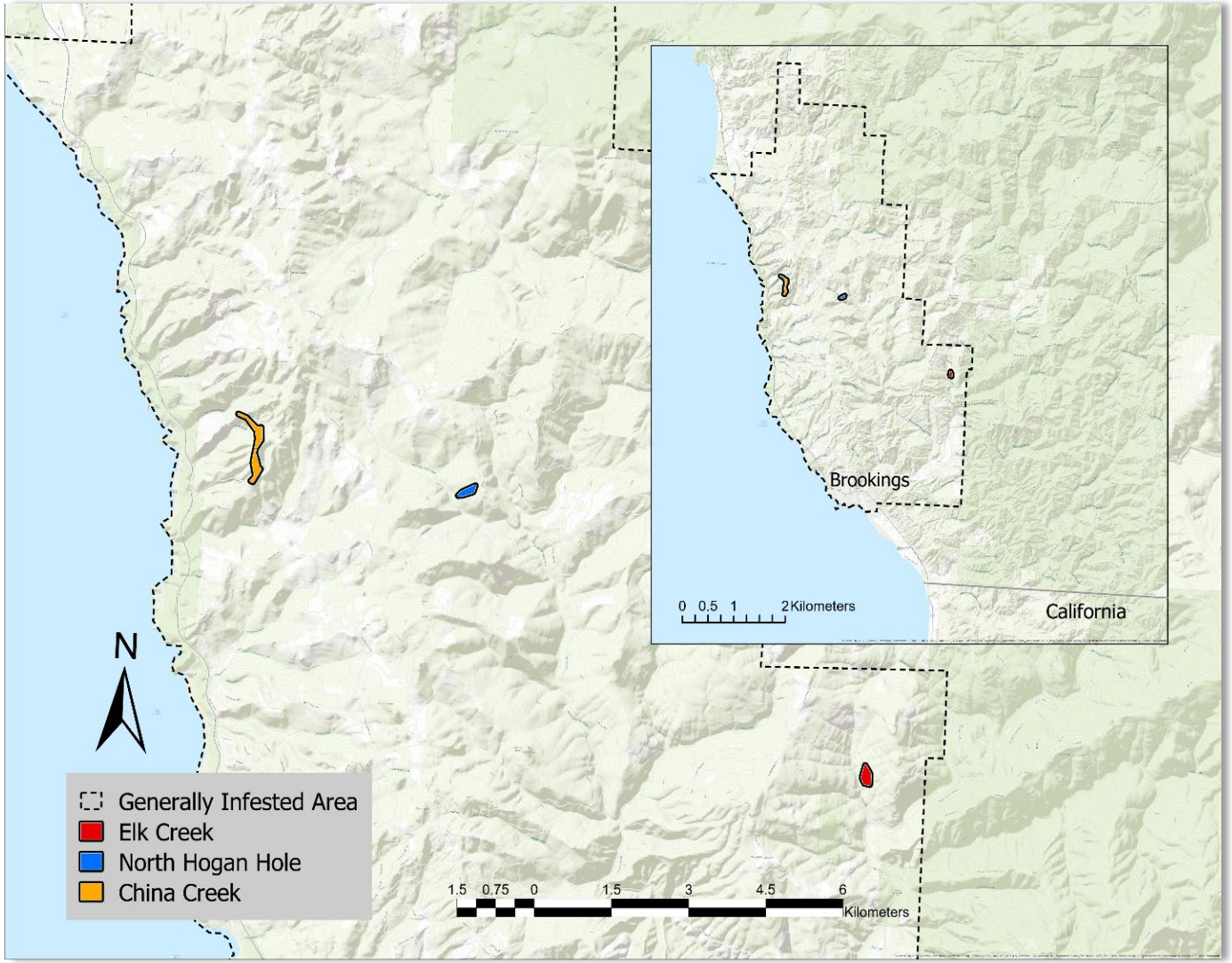
Eradication effectiveness:

- ‘Hack-and-squirt’ plus felling and burning is effective at reducing infection prevalence (Hansen, 2008; Daniels, 2021)
- The effectiveness of ‘hack-and-squirt’ as a stand alone treatment is unknown

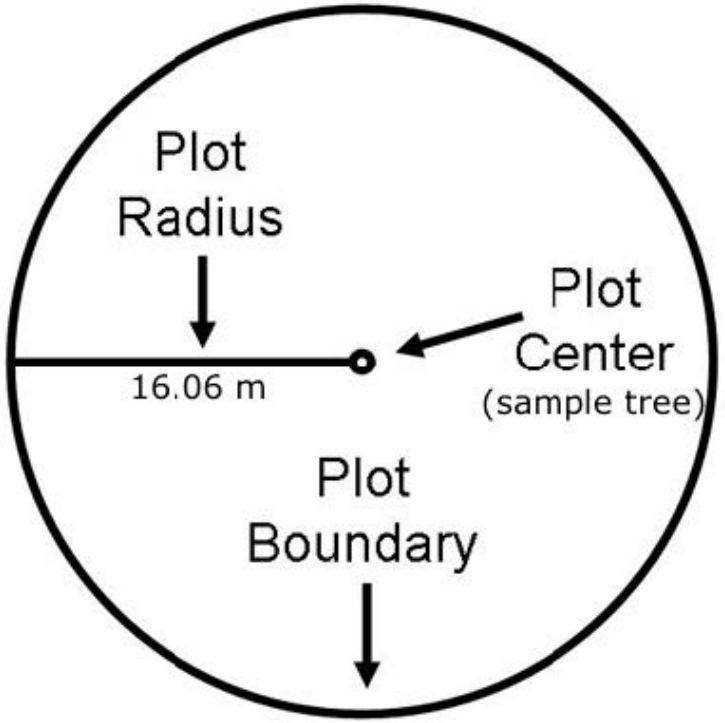
Epidemiology in Oregon:

- Reliance on regional weather data
- Microenvironmental differences unknown
- There is a need to further characterize local environmental optimums for sporulation and disease spread

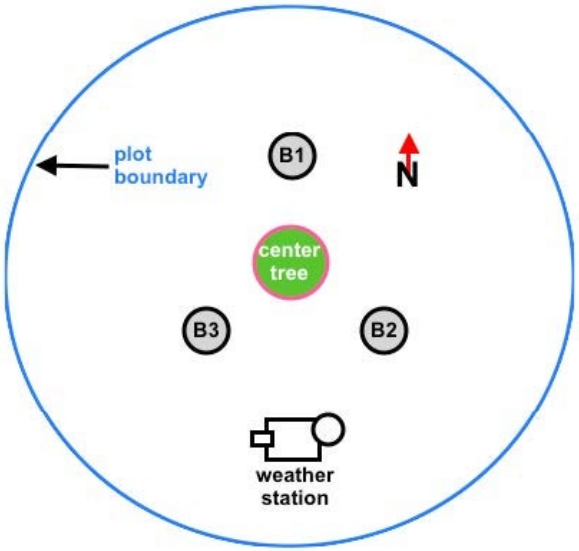
Materials & Methods



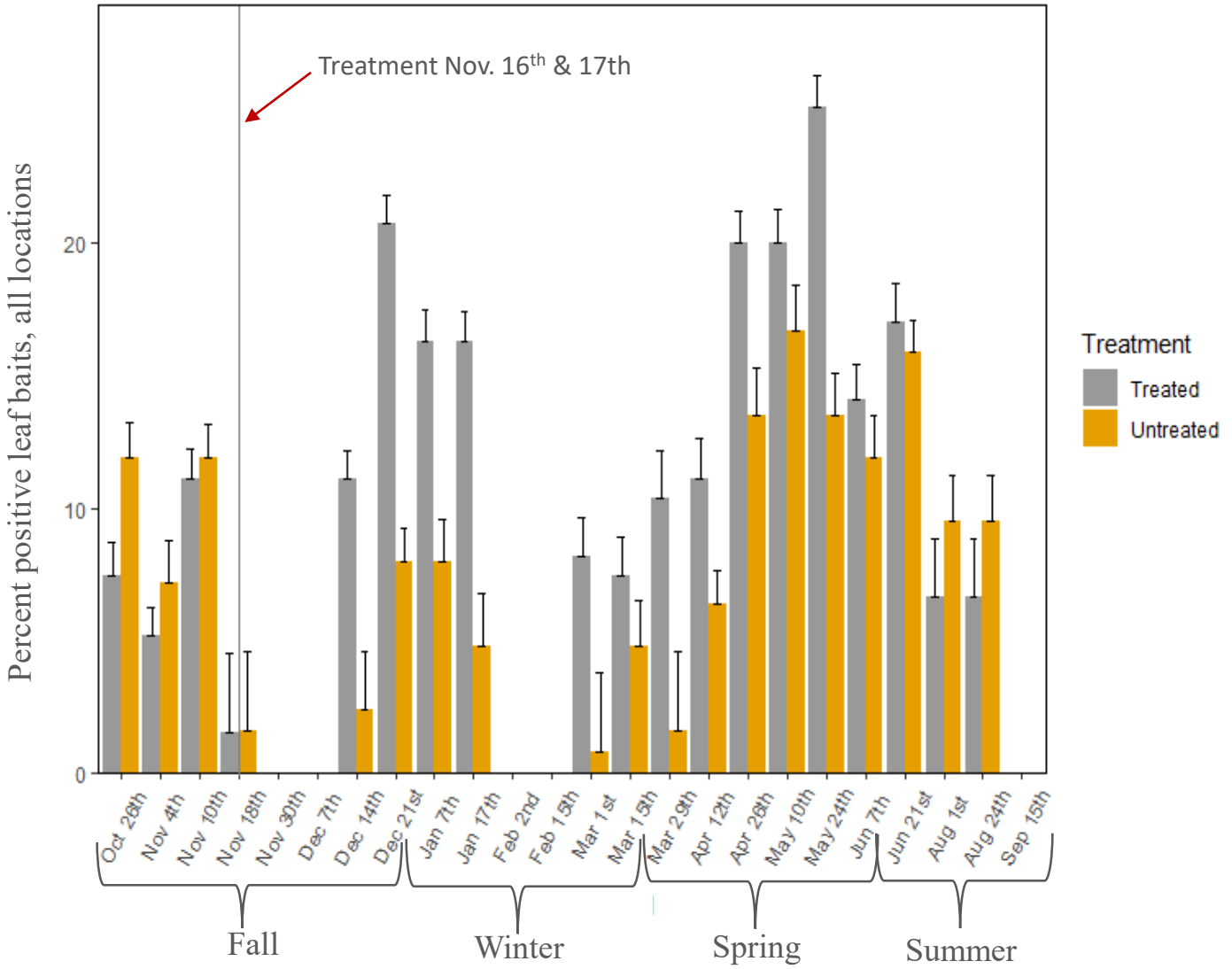
Materials & Methods



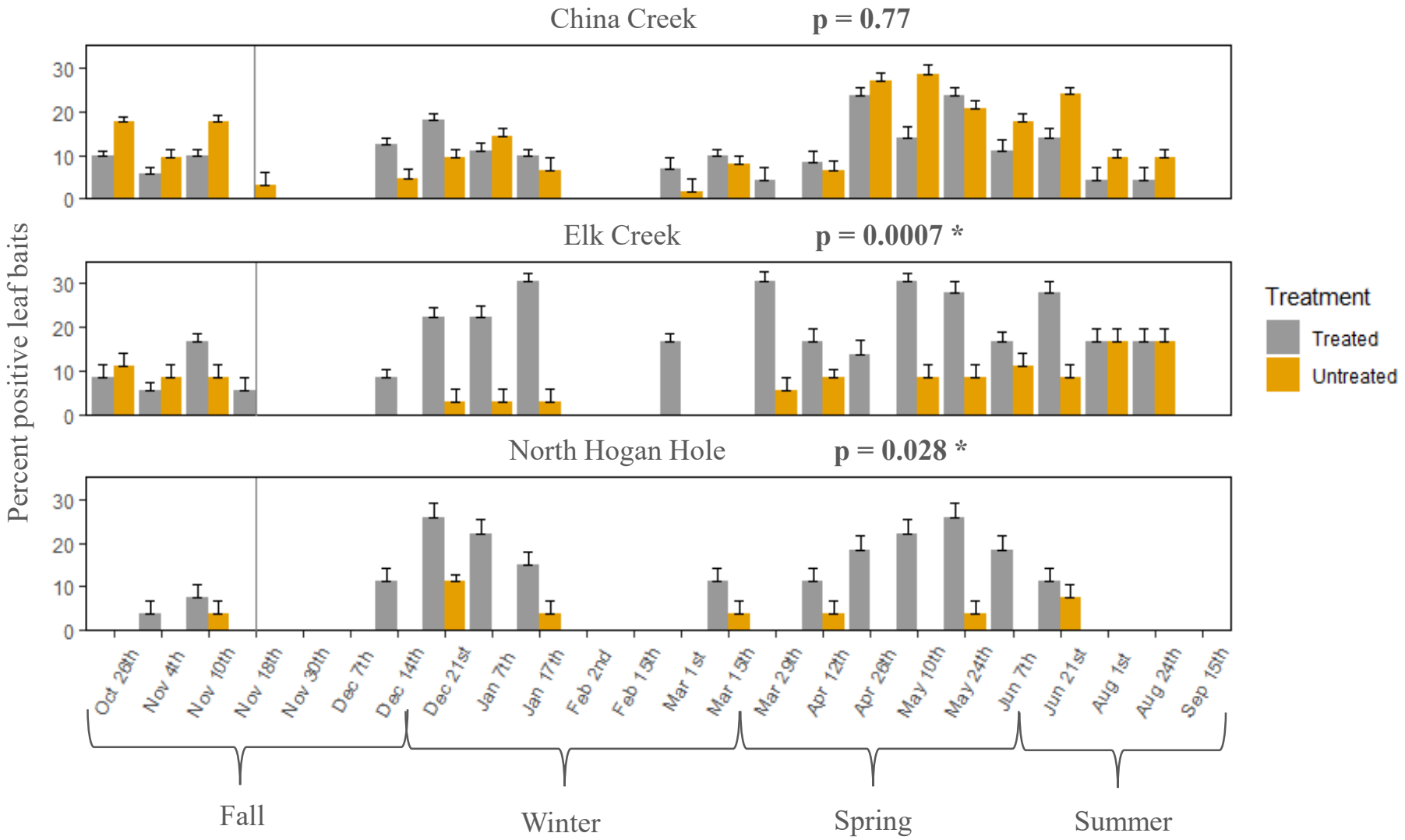
Materials & Methods



Results

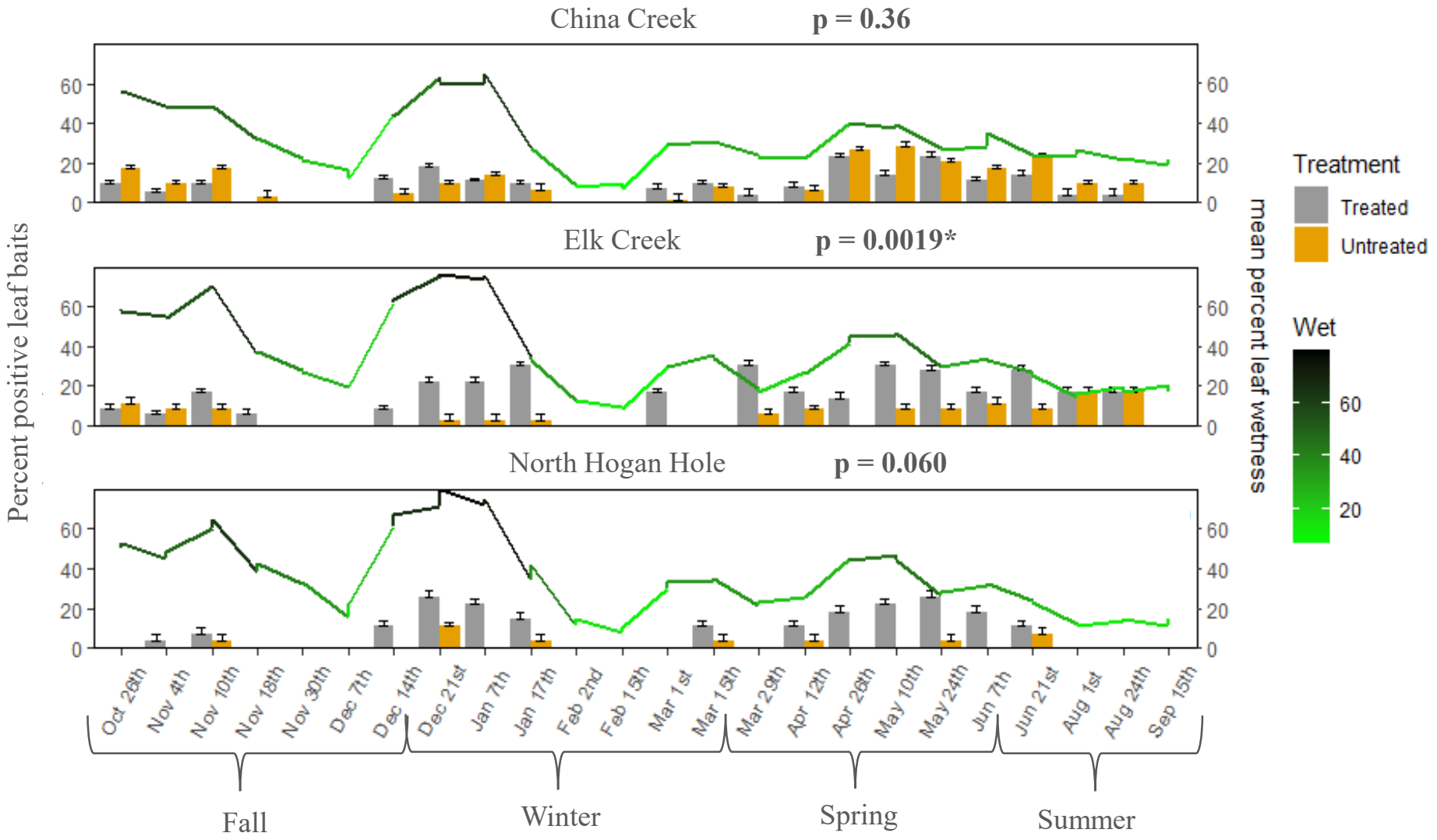

Treatment Nov. 16th & 17th
Percent positive leaf baits, all locations
0
10
20
Treatment
Treated
Untreated
Oct 28th
Nov 4th
Nov 10th
Nov 18th
Nov 30th
Dec 7th
Dec 14th
Dec 21st
Jan 7th
Jan 17th
Feb 2nd
Feb 15th
Mar 1st
Mar 15th
Mar 29th
Apr 12th
Apr 26th
May 10th
May 24th
Jun 7th
Jun 21st
Aug 1st
Aug 24th
Sep 15th
Fall
Winter
Spring
Summer

Results


China Creek
p = 0.77
Elk Creek
p = 0.0007 *
North Hogan Hole
p = 0.028 *
Percent positive leaf baits
0
10
20
30
Treatment
Treated
Untreated
Oct 26th
Nov 4th
Nov 10th
Nov 18th
Nov 30th
Dec 7th
Dec 14th
Dec 21st
Jan 7th
Jan 17th
Feb 2nd
Feb 15th
Mar 1st
Mar 15th
Mar 29th
Apr 12th
Apr 26th
May 10th
May 24th
Jun 7th
Jun 21st
Aug 1st
Aug 24th
Sep 15th
Fall
Winter
Spring
Summer

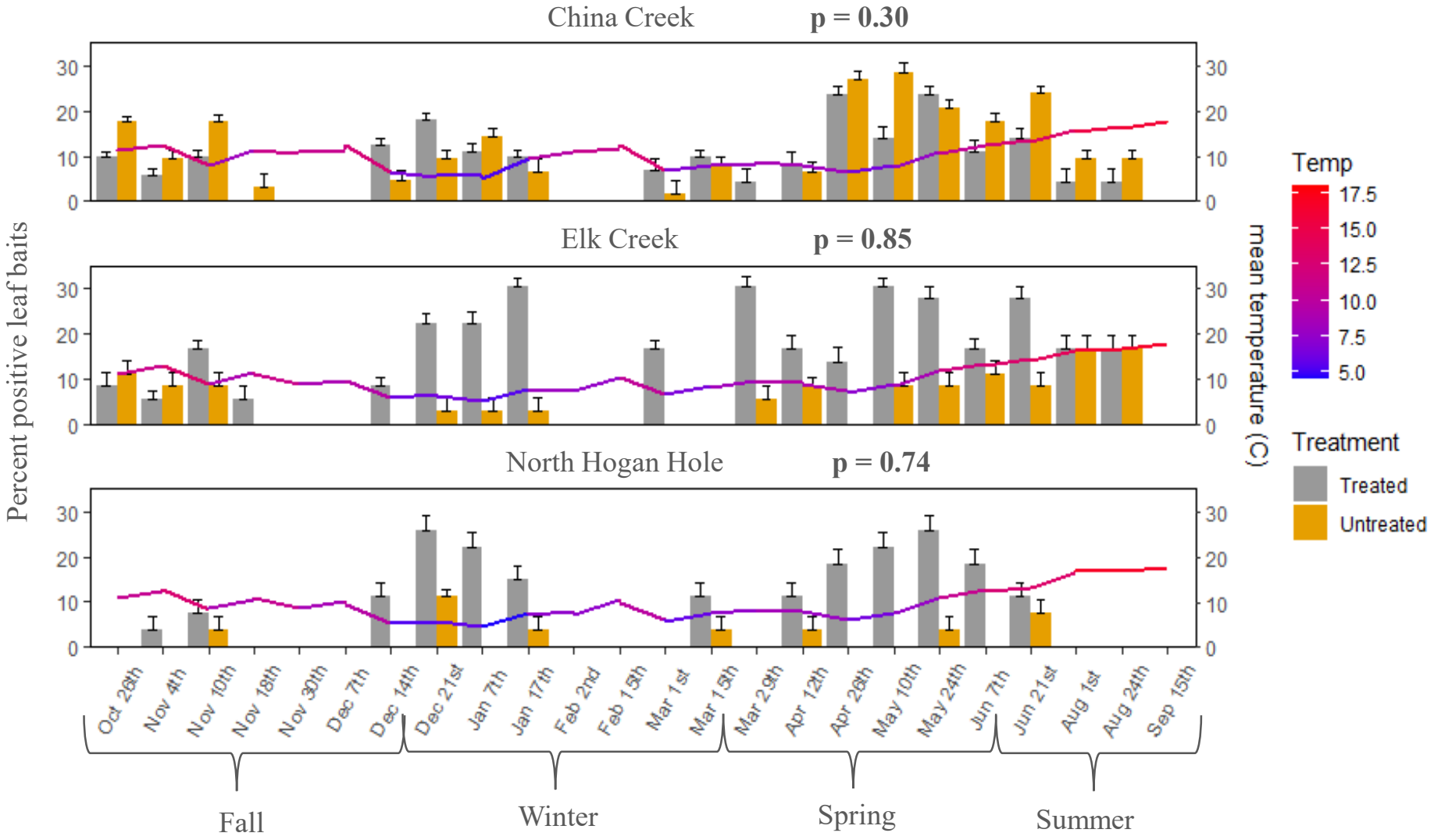
Results

Leaf Wetness



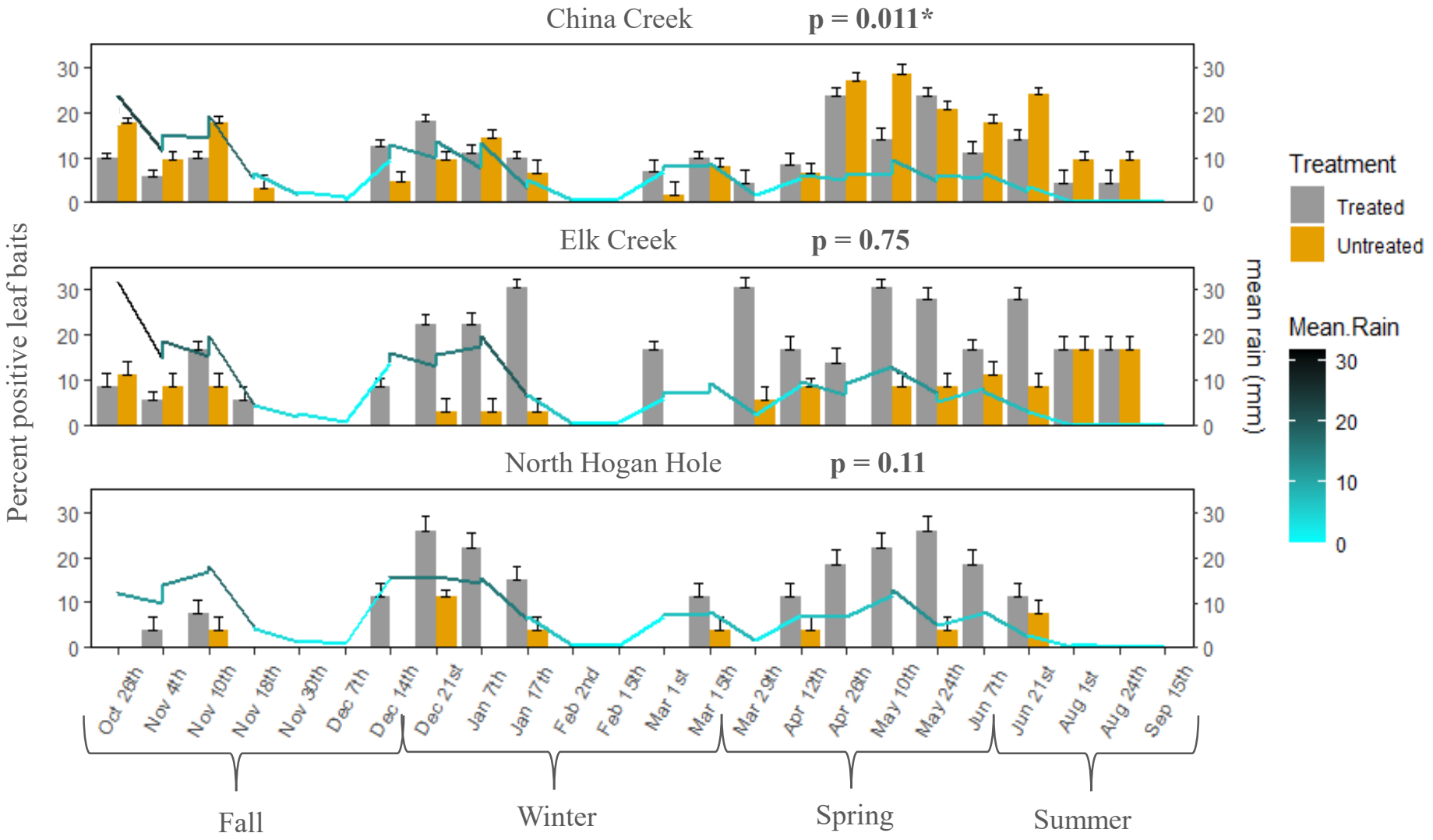
Results

Mean Temperature



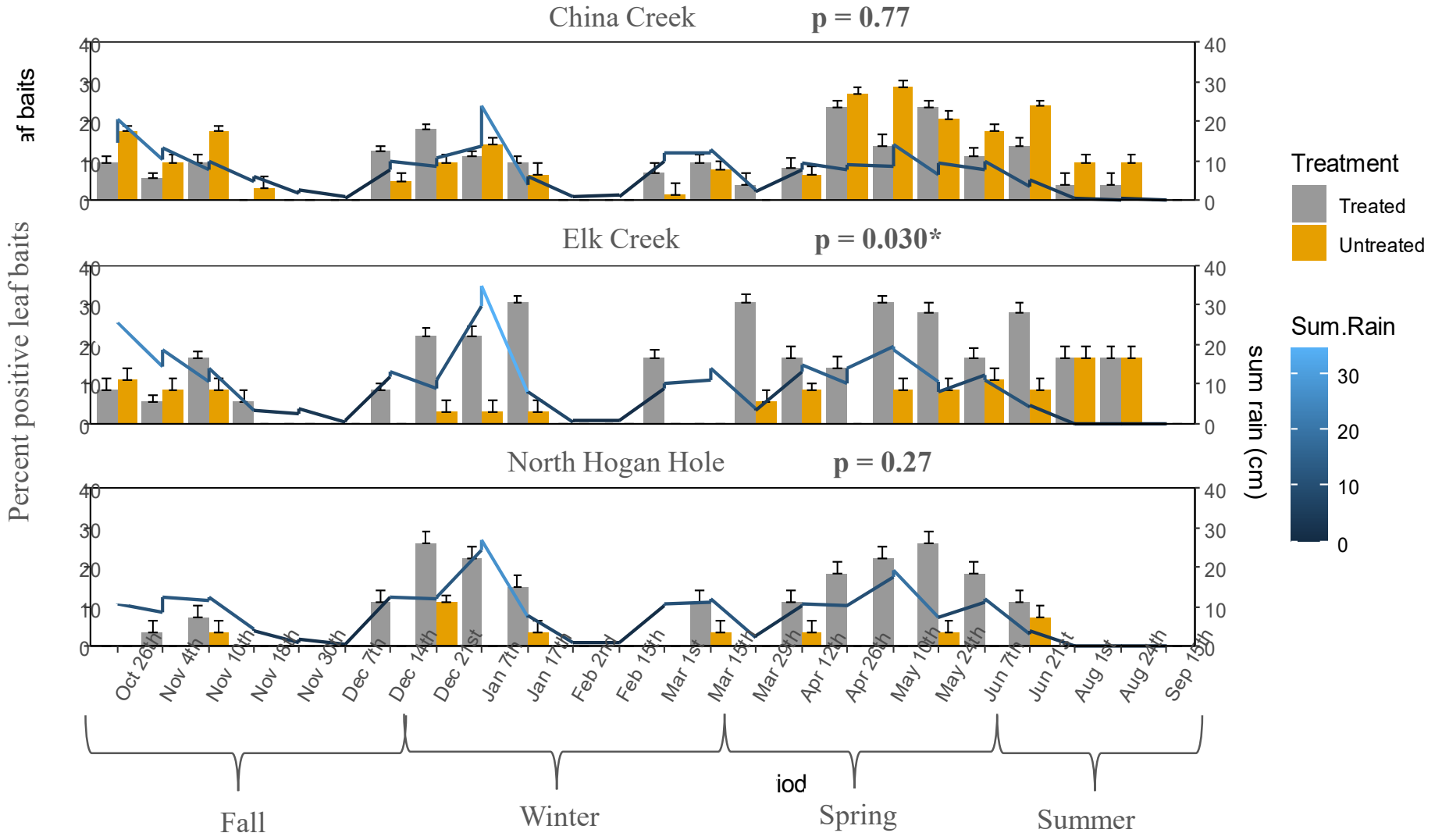
Results

Mean Rain



Results

Sum Rain



Thank you!