A Pathogen's Spatial Range is Not Constrained by Geographical Features in the Flax Rust Pathosystem

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Abstract

Climate change and shifting environmental conditions can allow pathogens to spread into previously unburdened areas. For plant pathogens, this dynamic has the potential to disrupt natural ecosystem equilibria and human agriculture, making predicting plant pathogen range shifts an increasingly important enterprise. Although such predictions will hinge on an accurate understanding of the determinants of pathogen range – namely the environmental, geographical, and host range characteristics that modulate local pathogen habitation – few studies to date have probed these in natural plant populations. Here, we characterize range determinants for the model system of Lewis flax (Linum Lewisii) and its pathogen, flax rust (Melamspora lini), in the Rocky Mountains. Transect surveys were performed to assess three relationships: i) the effect of geographical features – elevation, slope aspect, slope grade, and land-cover – on flax presence and density, ii) the effect of geographical features on flax rust presence and prevalence, and iii) the effects of flax's local population density and metapopulation structure on flax rust presence and prevalence. We found that flax population density, but not host metapopulation structure, influences the distribution of flax rust. Additionally, we showed that, while the distribution of flax was broadly constrained to a relatively narrow range of geographical and resulting environmental features, flax rust was evenly distributed across the full range of settings measured. These results indicate that a warming environment, which is expected to modulate such features, may restrict the optimal range of the plant more so than that of its pathogen. Importantly, our results also suggest that even if flax shifts its spatial range to escape increasing climatic pressures, flax rust will not face any significant barriers to track this movement.

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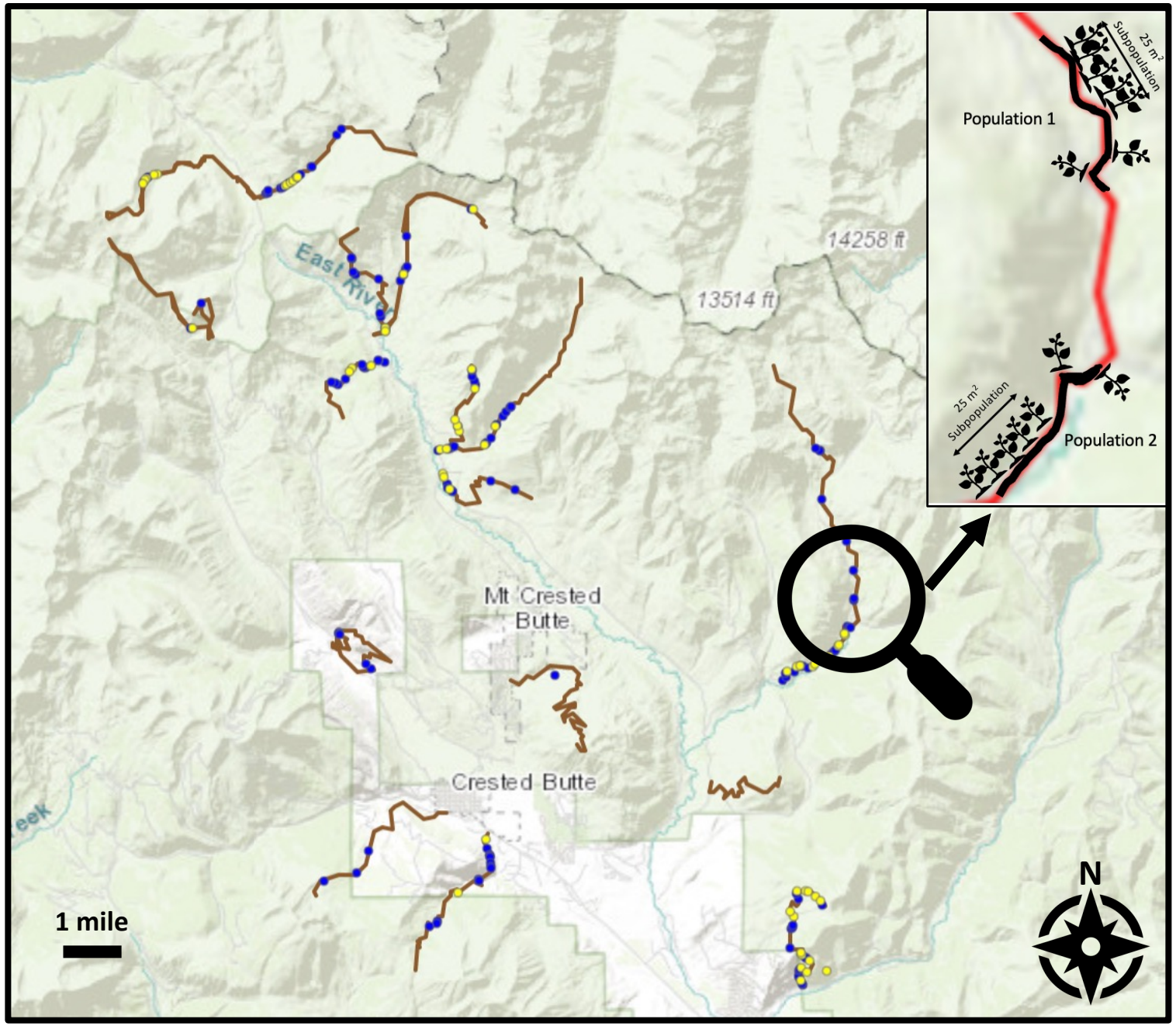
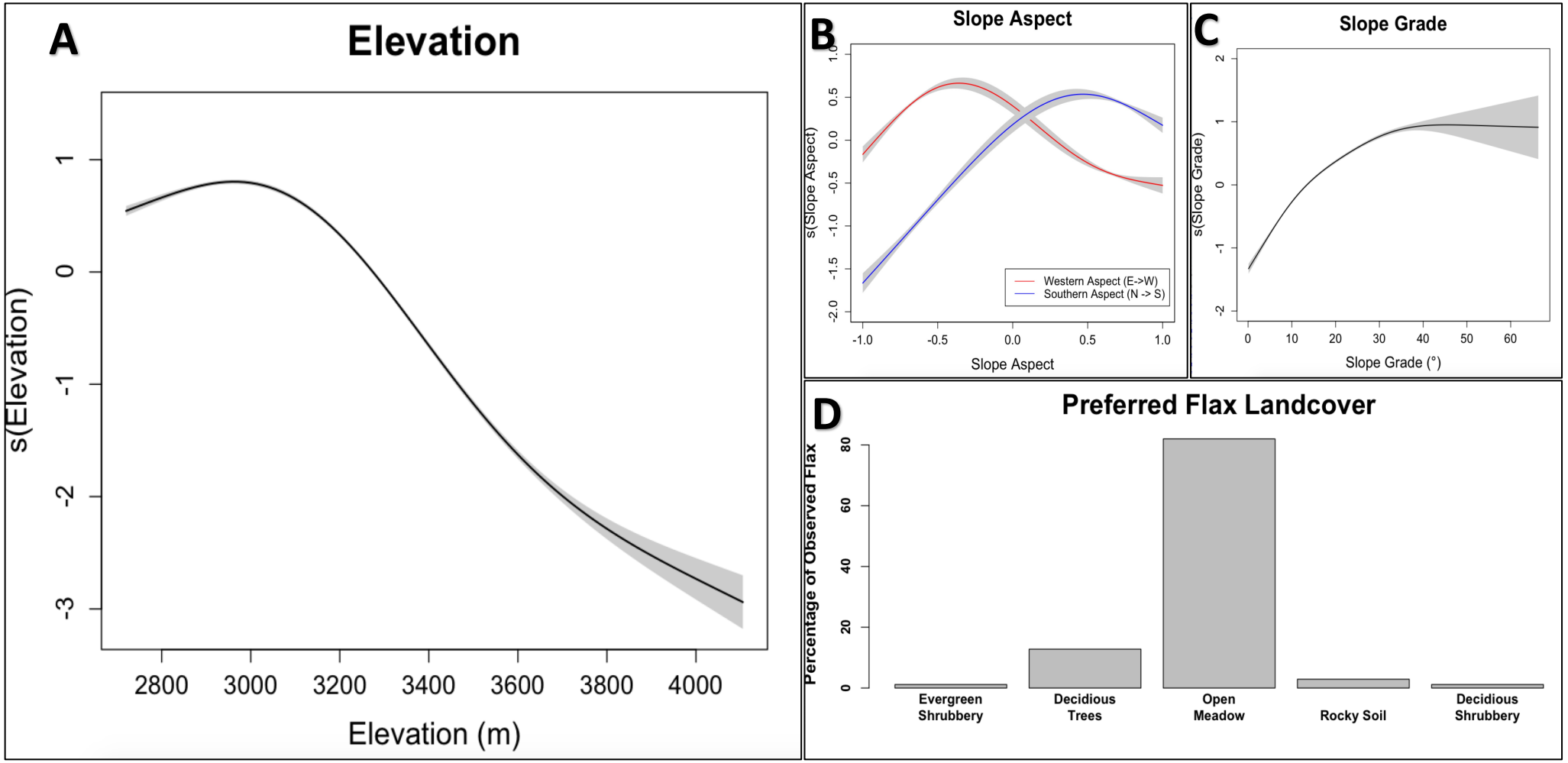
Main Text Figures:

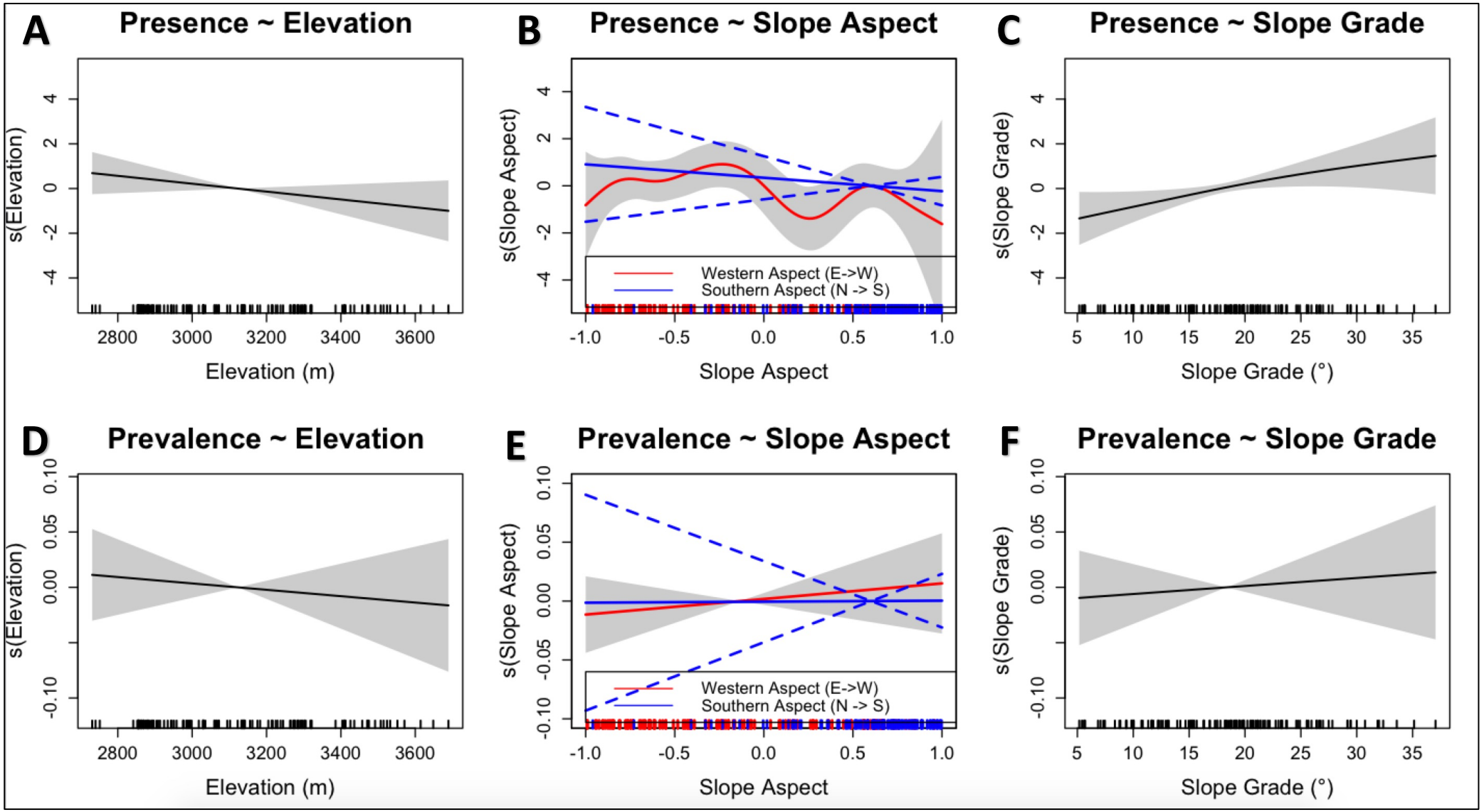
1


14258 ft
13514 ft
East River
Mt Crested Butte
Crested Butte
1 mile
N
Population 1
Population 2
25 m² Subpopulation
25 m² Subpopulation

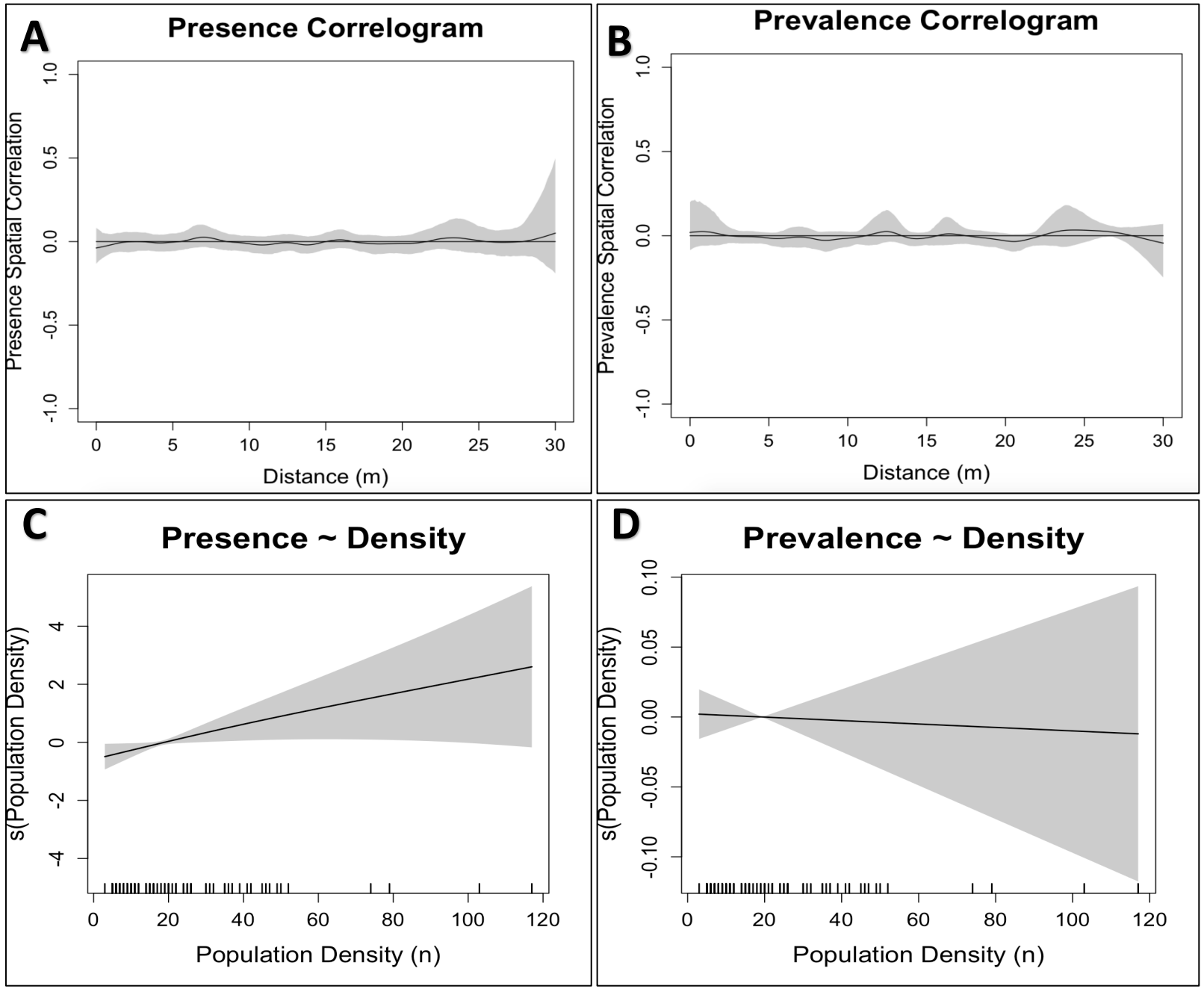
2


A
Elevation
s(Elevation)
1
0
-1
-2
-3
2800
3000
3200
3400
3600
3800
4000
Elevation (m)
B
Slope Aspect
s(Slope Aspect)
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-1.0
-0.5
0.0
0.5
1.0
Slope Aspect
Western Aspect (E->W)
Southern Aspect (N -> S)
C
Slope Grade
s(Slope Grade)
2
1
0
-1
-2
0
10
20
30
40
50
60
Slope Grade (°)
D
Preferred Flax Landcover
Percentage of Observed Flax
0
20
40
60
80
Evergreen Shrubbery
Decidious Trees
Open Meadow
Rocky Soil
Decidious Shrubbery

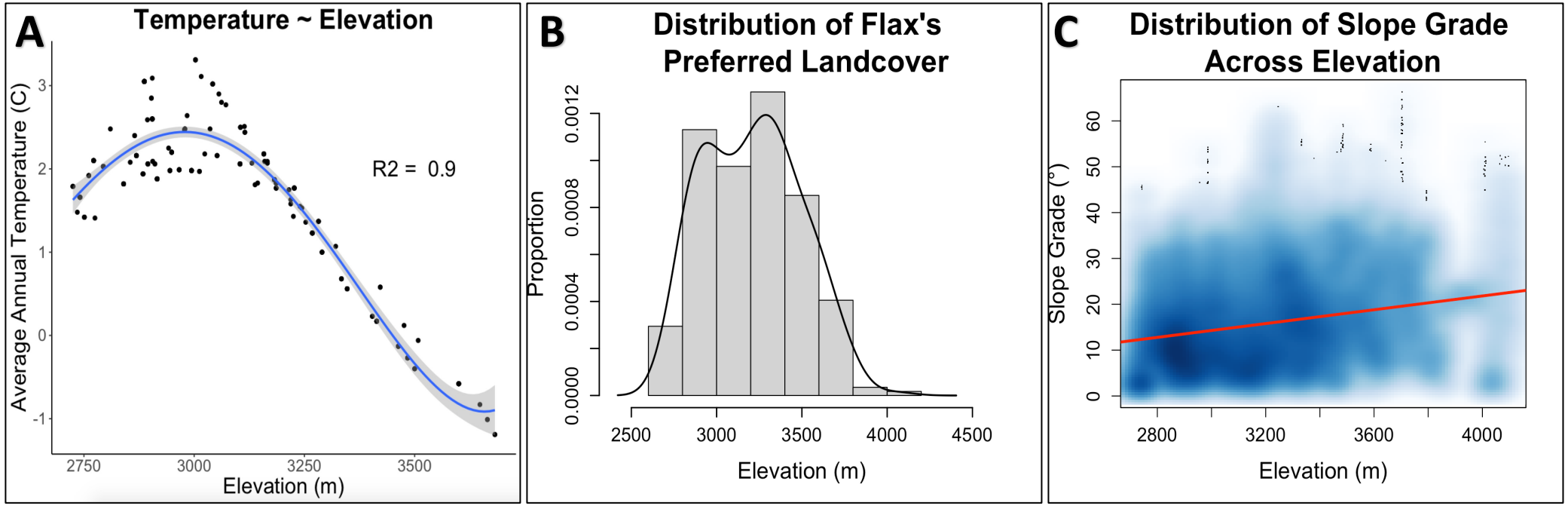
3


A
Presence ~ Elevation
s(Elevation)
Elevation (m)
B
Presence ~ Slope Aspect
s(Slope Aspect)
Slope Aspect
Western Aspect (E->W)
Southern Aspect (N -> S)
C
Presence ~ Slope Grade
s(Slope Grade)
Slope Grade (°)
D
Prevalence ~ Elevation
s(Elevation)
Elevation (m)
E
Prevalence ~ Slope Aspect
s(Slope Aspect)
Slope Aspect
Western Aspect (E->W)
Southern Aspect (N -> S)
F
Prevalence ~ Slope Grade
s(Slope Grade)
Slope Grade (°)

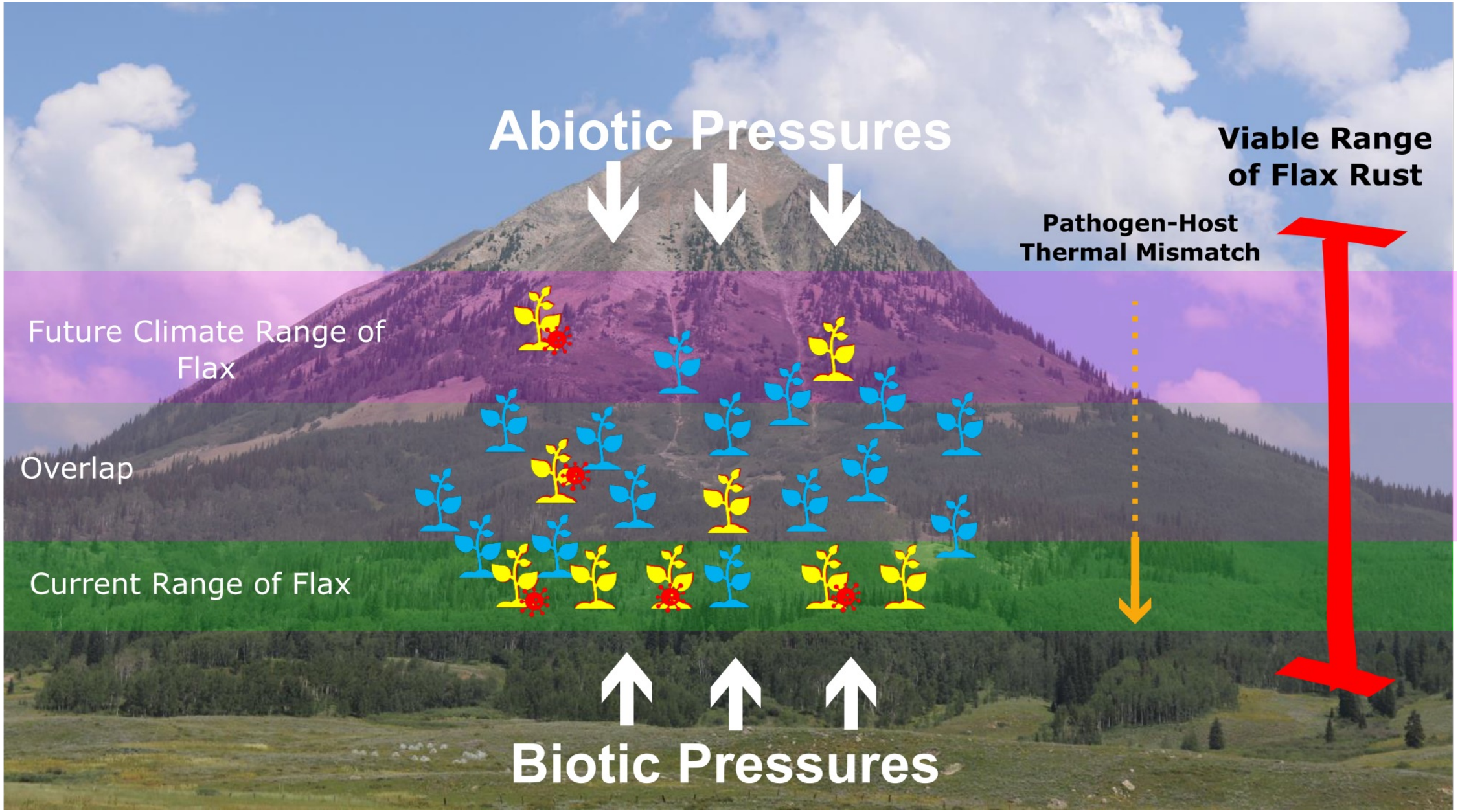
4


A
Presence Correlogram
Presence Spatial Correlation
1.0
0.5
0.0
-0.5
-1.0
0
5
10
15
20
25
30
Distance (m)
B
Prevalence Correlogram
Prevalence Spatial Correlation
1.0
0.5
0.0
-0.5
-1.0
0
5
10
15
20
25
30
Distance (m)
C
Presence ~ Density
s(Population Density)
4
2
0
-2
-4
0
20
40
60
80
100
120
Population Density (n)
D
Prevalence ~ Density
s(Population Density)
0.10
0.05
0.00
-0.05
-0.10
0
20
40
60
80
100
120
Population Density (n)

5

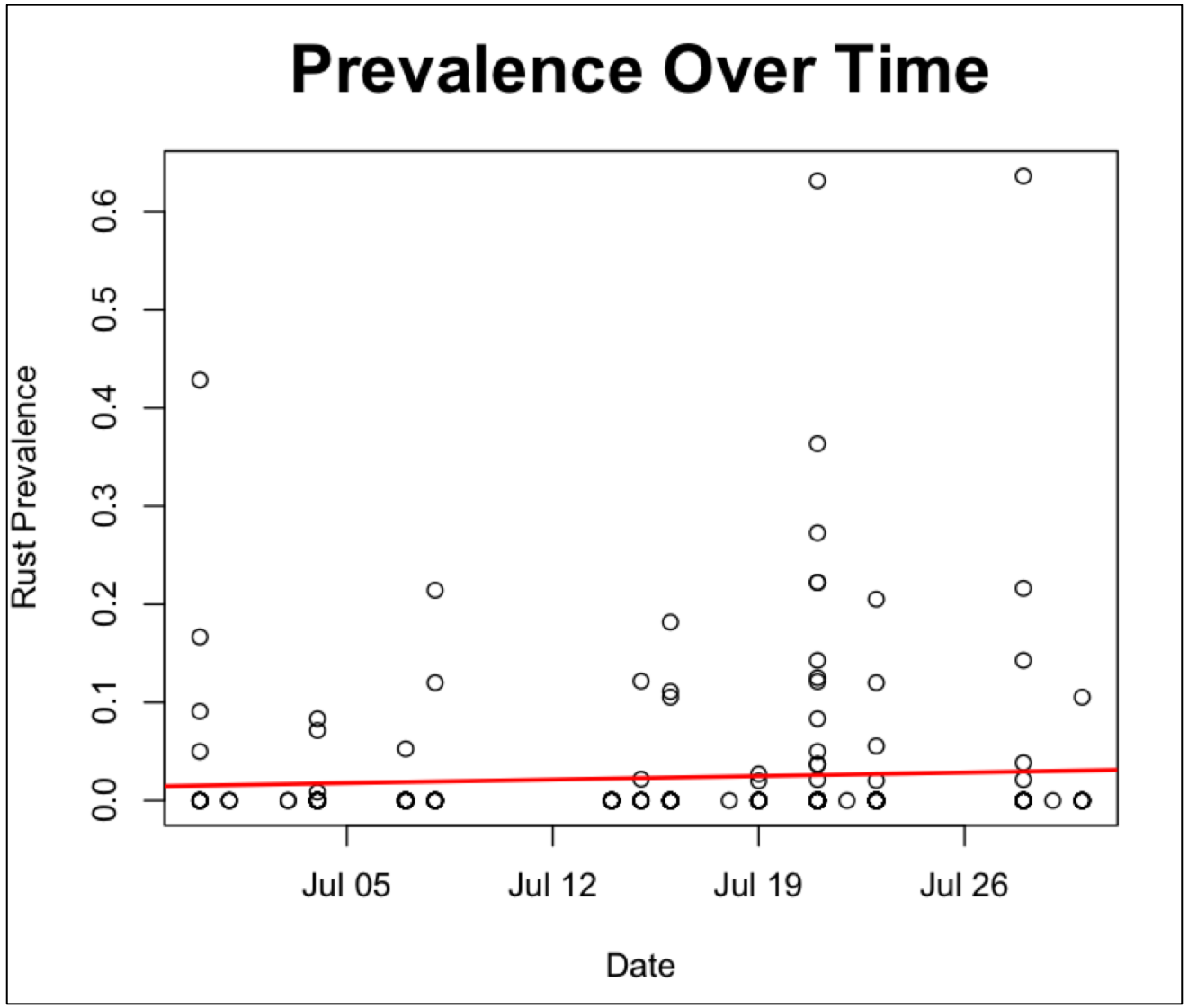

A
Temperature ~ Elevation
Average Annual Temperature (C)
3
2
1
0
-1
R2 = 0.9
2750
3000
3250
3500
Elevation (m)
B
Distribution of Flax's Preferred Landcover
Proportion
0.0000
0.0004
0.0008
0.0012
2500
3000
3500
4000
4500
Elevation (m)
C
Distribution of Slope Grade Across Elevation
Slope Grade (°)
0
10
20
30
40
50
60
2800
3200
3600
4000
Elevation (m)

6

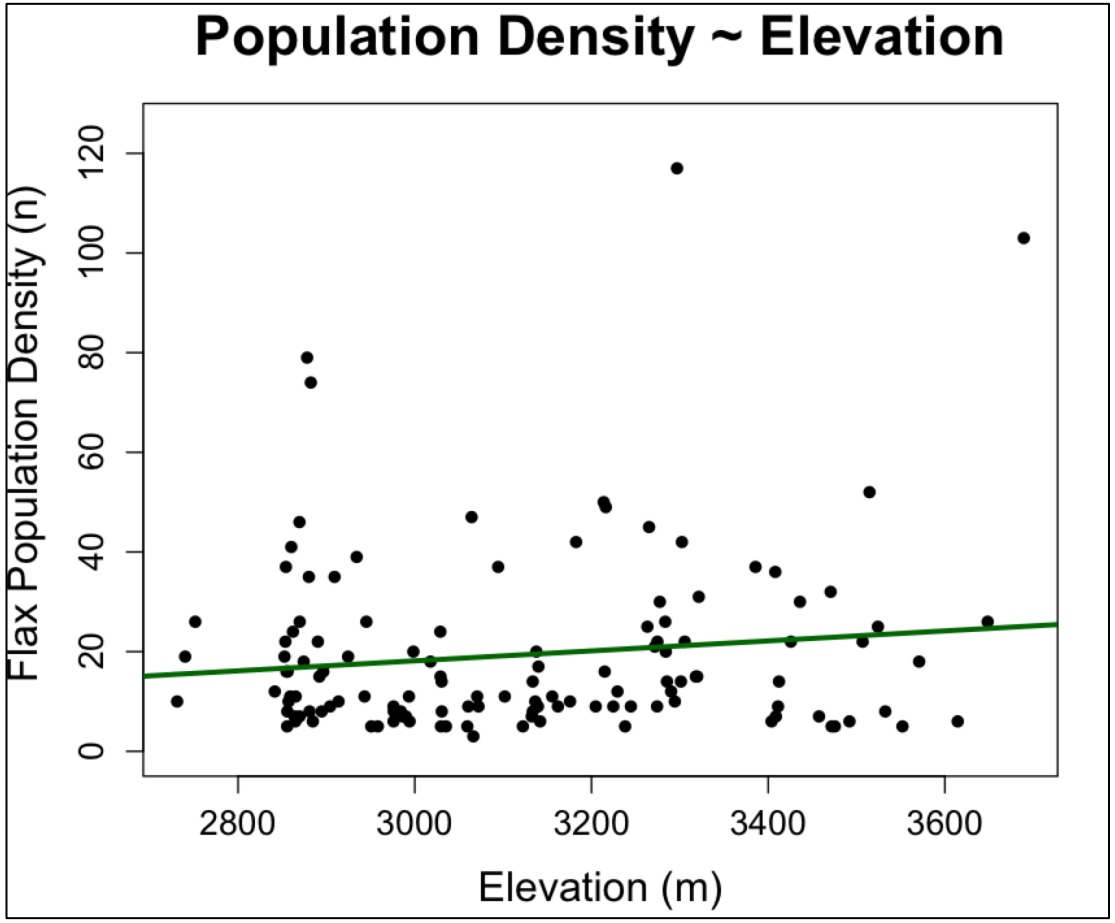

Abiotic Pressures
Viable Range of Flax Rust
Pathogen-Host Thermal Mismatch
Future Climate Range of Flax
Overlap
Current Range of Flax
Biotic Pressures

Appendix Figures

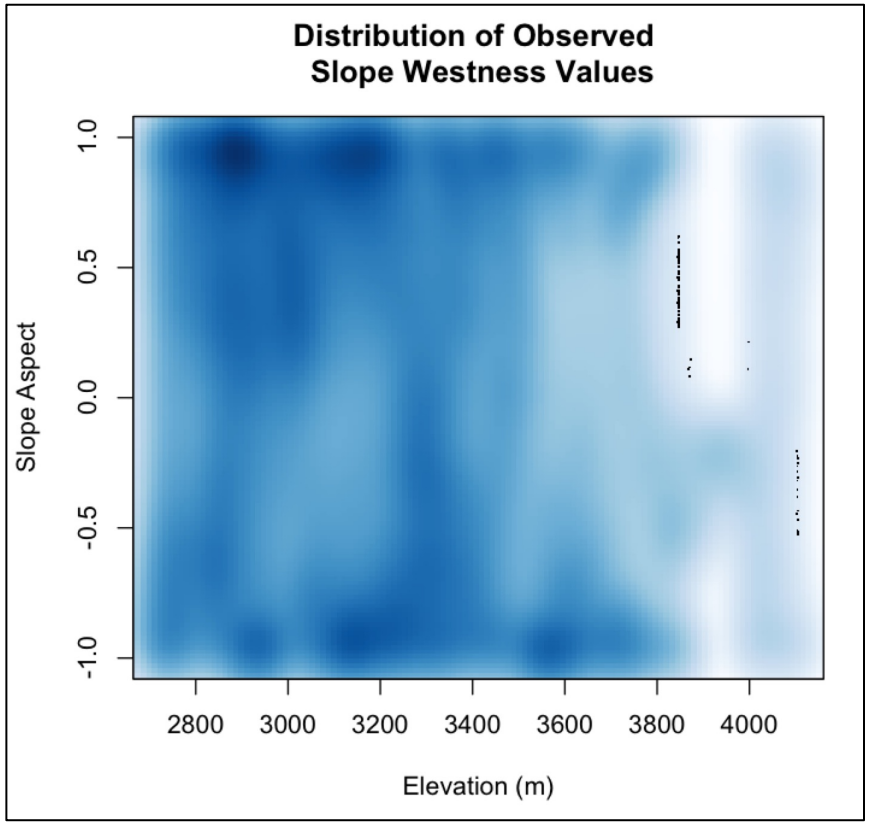
1

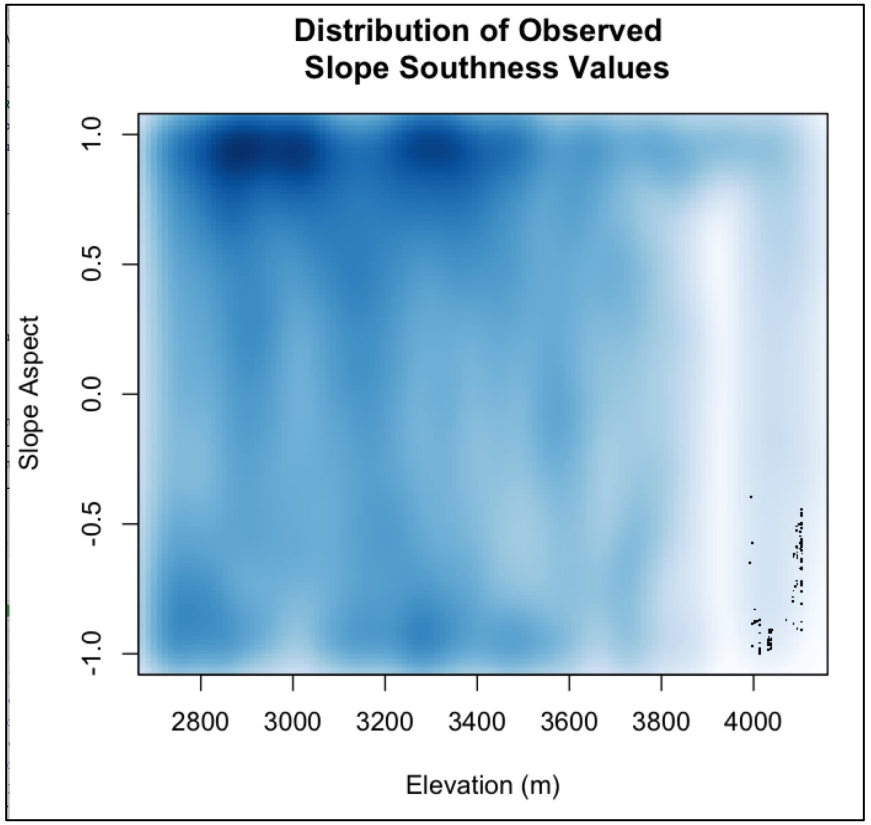

Prevalence Over Time
Rust Prevalence
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Jul 05
Jul 12
Jul 19
Jul 26
Date

2

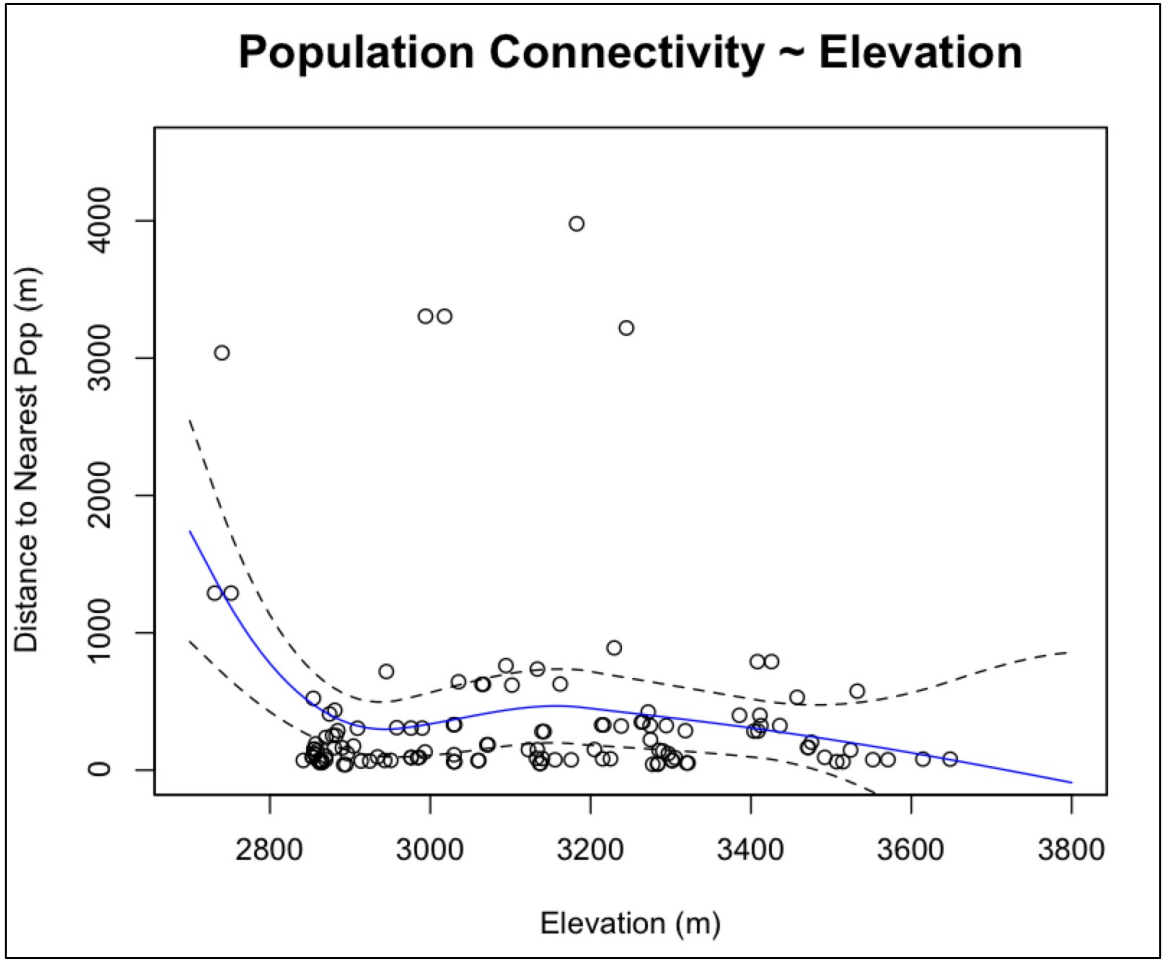

Population Density ~ Elevation
Flax Population Density (n)
0
20
40
60
80
100
120
2800
3000
3200
3400
3600
Elevation (m)

3


Distribution of Observed
Slope Westness Values
Slope Aspect
1.0
0.5
0.0
-0.5
-1.0
2800
3000
3200
3400
3600
3800
4000
Elevation (m)


Distribution of Observed
Slope Southness Values
Slope Aspect
1.0
0.5
0.0
-0.5
-1.0
2800
3000
3200
3400
3600
3800
4000
Elevation (m)

4


Population Connectivity ~ Elevation
Distance to Nearest Pop (m)
0
1000
2000
3000
4000
2800
3000
3200
3400
3600
3800
Elevation (m)