Invasive pest effects on tree demographics and equilibrium carbon storage capacity across the northeastern United States

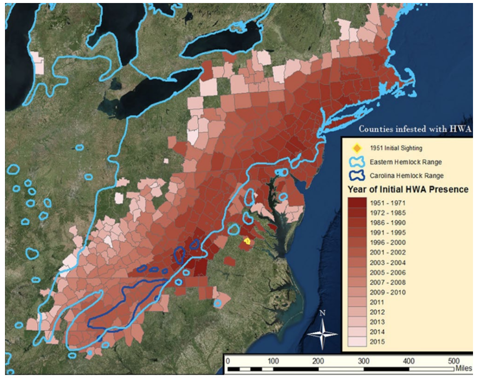
Jeff Garnas[1], Carlisle Bascom[1], Carrie Fearer[2], Andrew Liebhold[3], Randy Morin[3] , Songlin Fei[4]

1 University of New Hampshire

2 VIRGINIA TECH

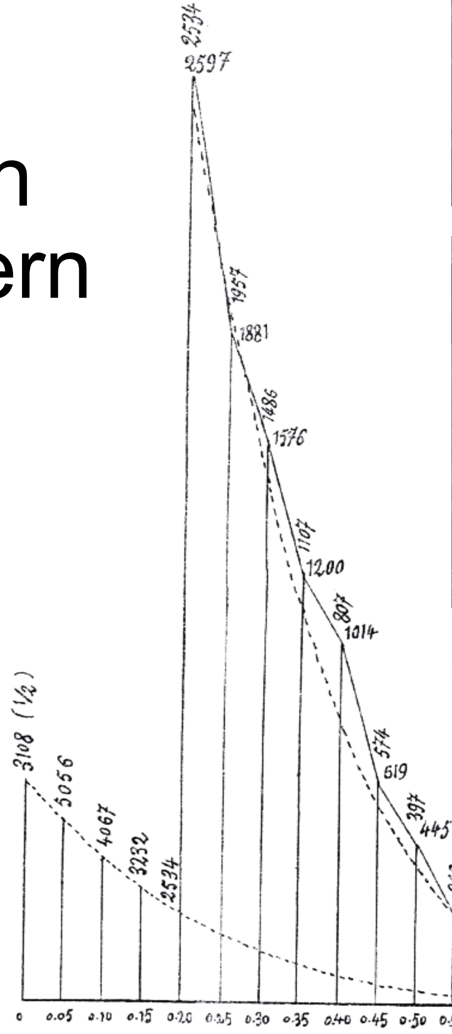
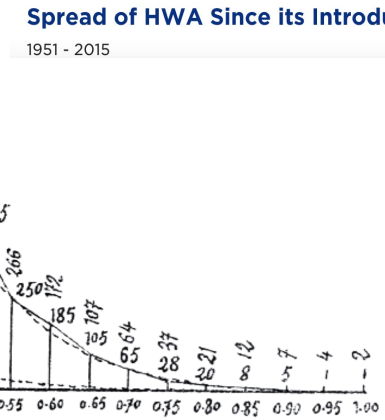
3

4 PURDUE UNIVERSITY



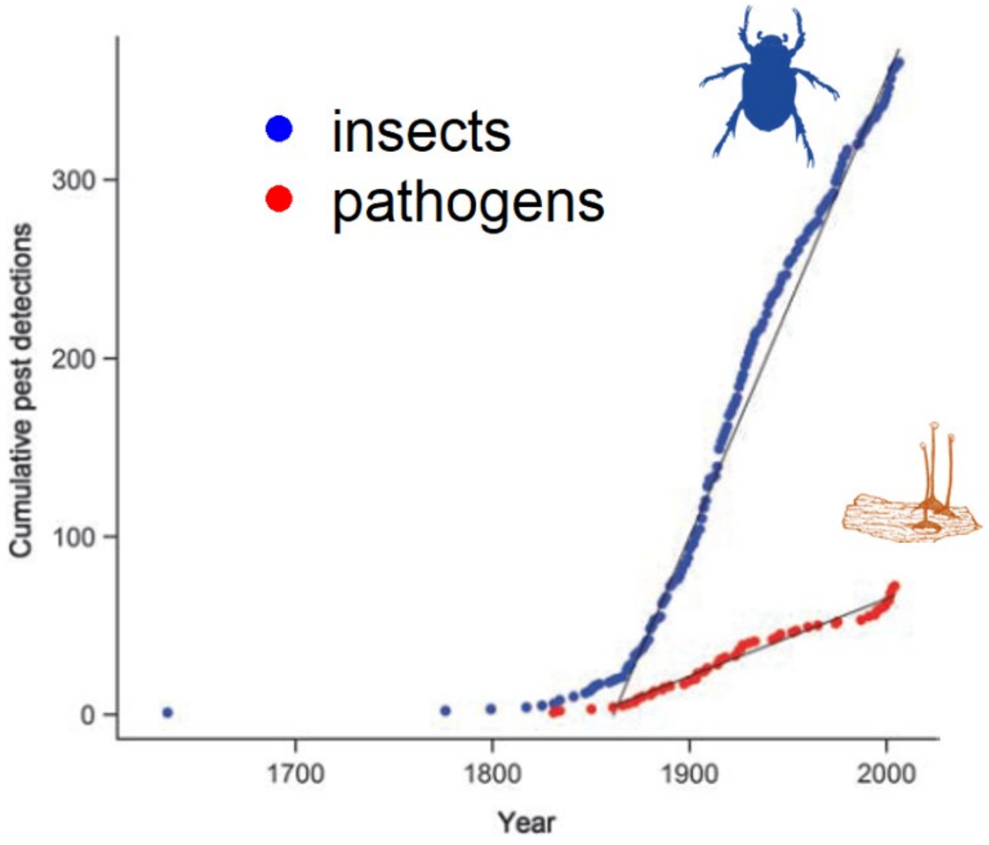
Spread of HWA Since its Introduction

1951 - 2015

Nonnative pests and pathogens are a dominant disturbance in temperate forests worldwide

Steady accrual of insect pests and pathogens, U.S.



Aukema 2010

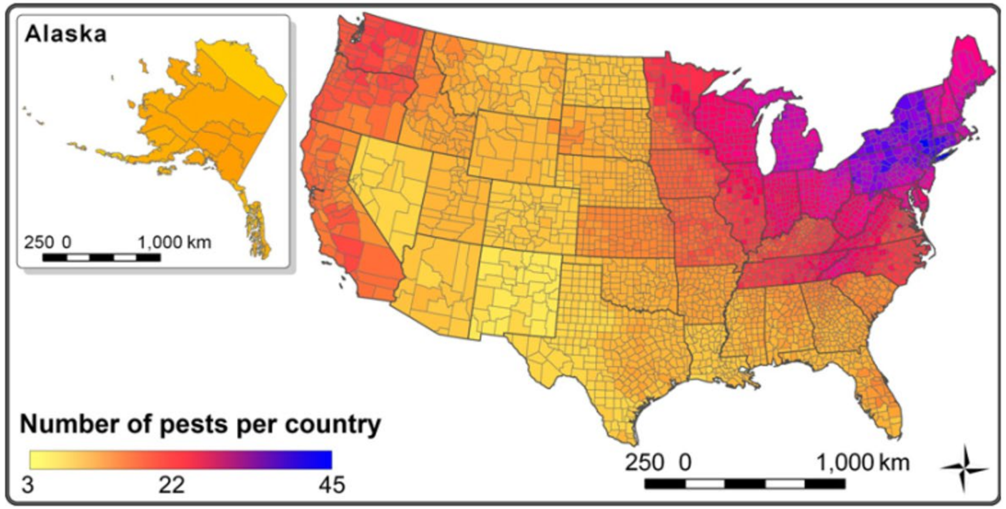
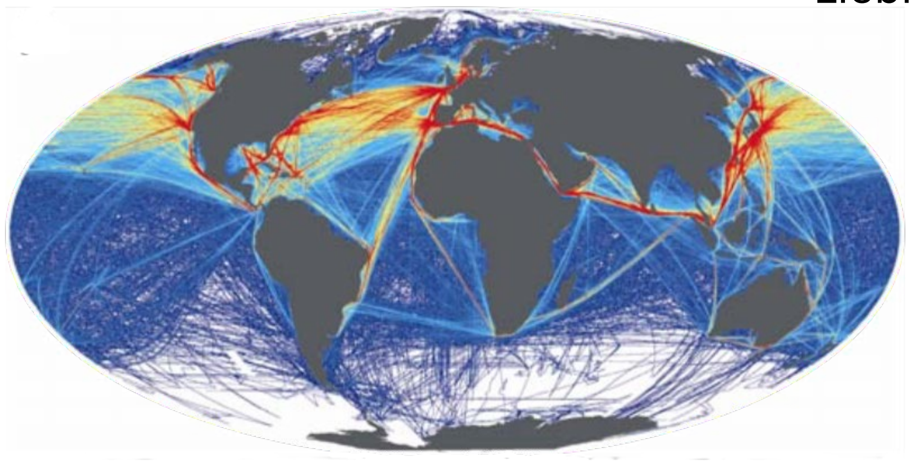


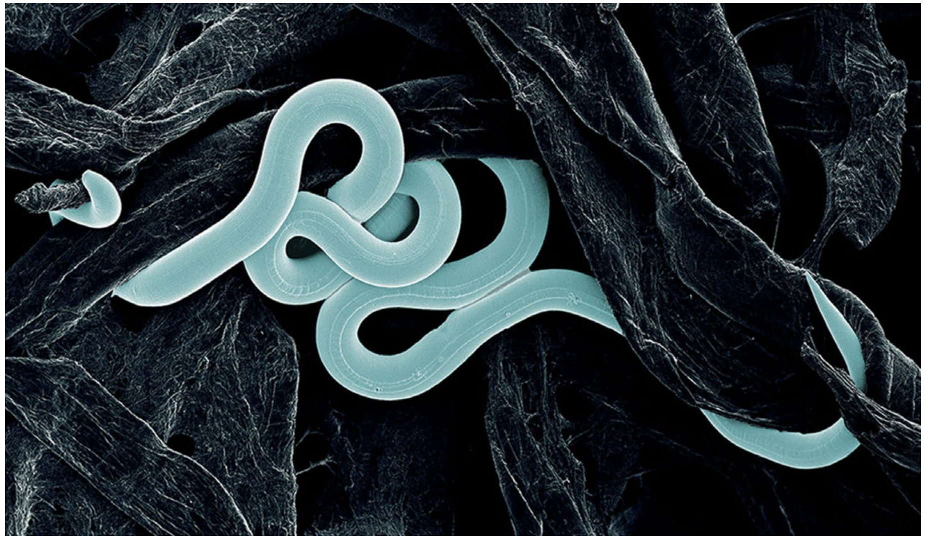
Figure 1 Numbers of damaging invasive forest pests per county.

Liebhold 2013



Halpern 2008

Historical, active, and emerging threats



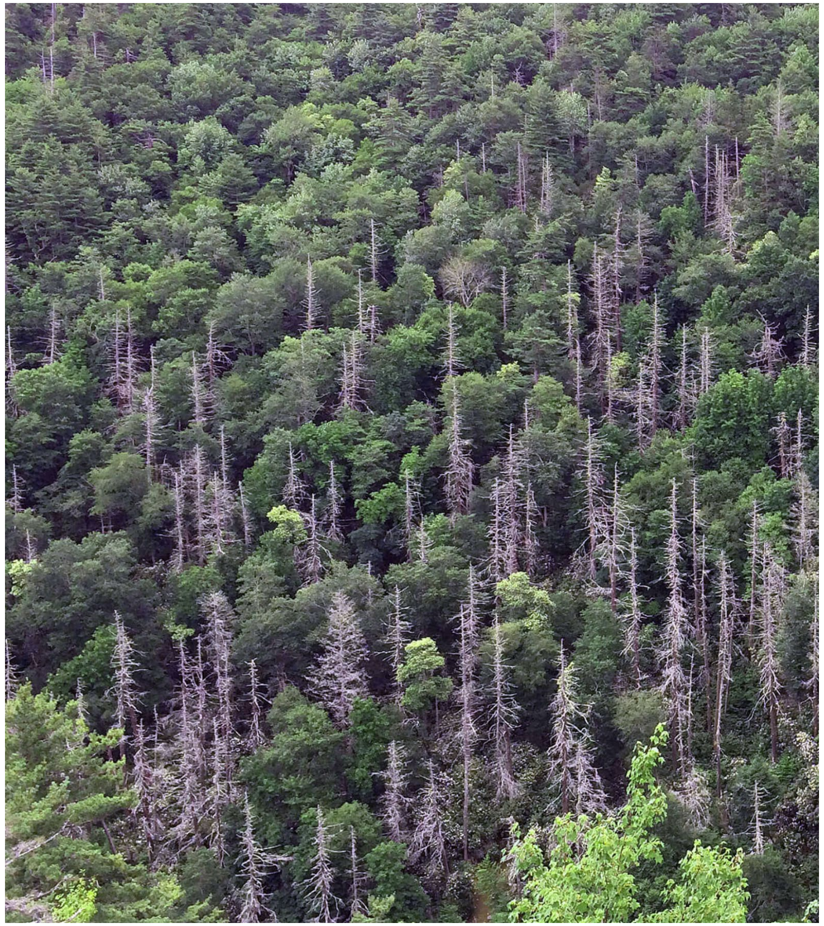
Loss of foundation species
Chestnut blight


North Carolina, circa 1920


Largest chestnut in NH, 2023

Loss of foundation species

Chestnut blight, Hemlock wooly adelgid, Emerald ash borer



WI Dept. Nat. Res. 2018

Shifts in biomass storage capacity, forest size and age structure, and demographic rates

BBD impacts

Journal of Ecology

British Ecological Society

Journal of Ecology 2011, **99**, 532–541 doi: 10.1111/j.1365-2745.2010.01791.x

Subcontinental impacts of an invasive tree disease on forest structure and dynamics

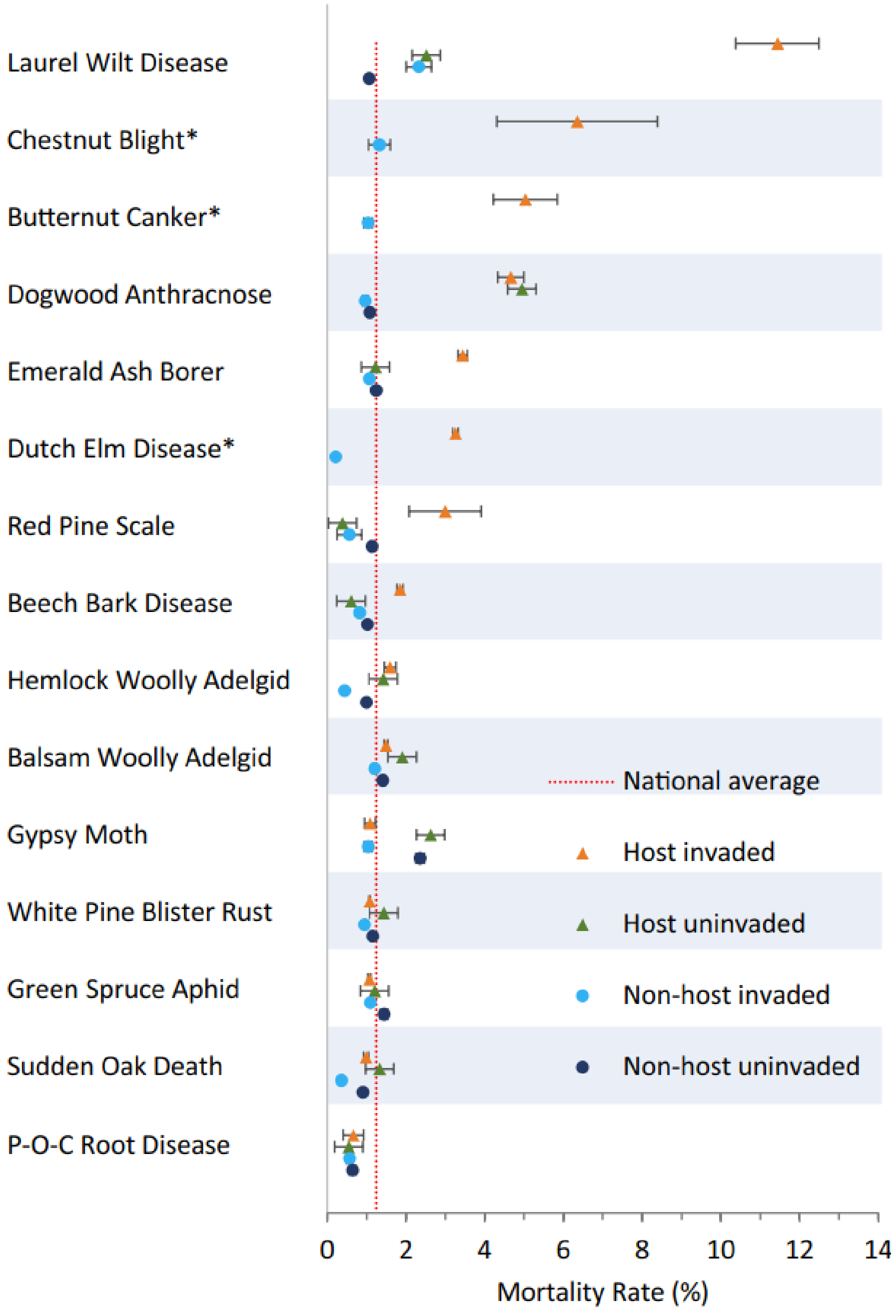
Jeffrey R. Garnas[1]*, Matthew P. Ayres[1], Andrew M. Liebhold[2] and Celia Evans[3]

[1]Department of Biological Sciences, Dartmouth College, Hanover, NH 03755, USA; [2]US Forest Service Northern Research Station, 180 Canfield St, Morgantown, WV 26505, USA; and [3]Department of Science, Paul Smith's College, Paul Smiths, NY 12970, USA

Proliferation, not extirpation, of beech stems

Beech forests have seen a sustained shift to smaller, denser forests over time.

Garnas et al. 2011

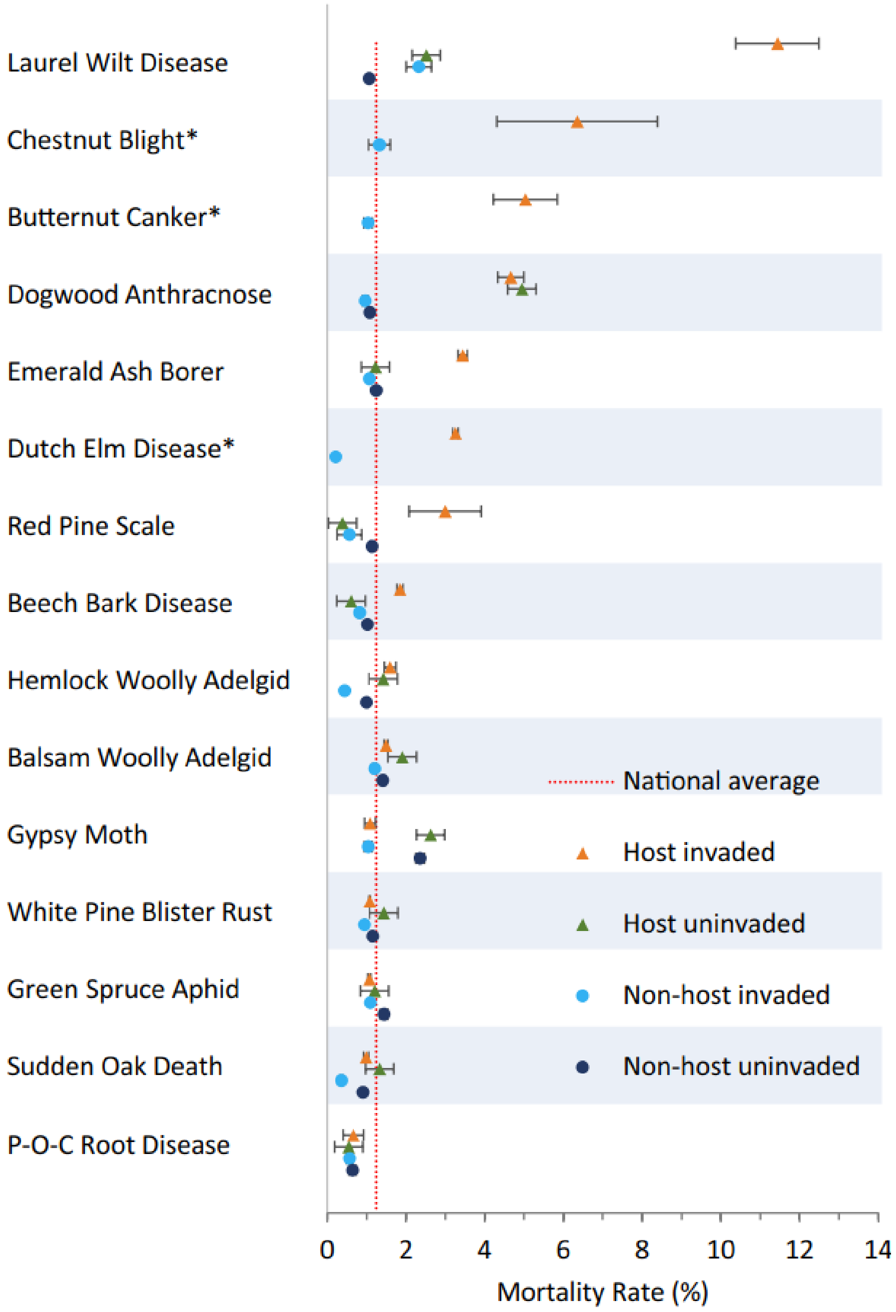


Biomass losses resulting from insect and disease invasions in US forests

Songlin Fei[a,1], Randall S. Morin[b], Christopher M. Oswalt[c], and Andrew M. Liebhold[d]

Pest common name	Host biomass, TgC Invaded	Host biomass, TgC Uninvaded
Balsam woolly adelgid	317.17	292.47
Beech bark disease	90.22	63.71
Butternut canker[†]	1.09	—
Chestnut blight[†]	0.03	—
Dogwood anthracnose	0.93	2.31
Dutch elm disease[†]	114.38	—
Emerald ash borer	81.87	210.81
Green spruce aphid	146.77	280.30
Gypsy moth	897.77	2,174.13
Hemlock woolly adelgid	59.40	58.03
Laurel wilt disease	0.55	18.14
Port Orford cedar root disease	2.77	0.27
Red pine scale	0.28	52.60
Sudden oak death	76.68	547.60
White pine blister rust	236.46	17.02

Fei et al. 2019



Approach: Re-examine eastern forest dynamics from the perspective of shifting tree demographics as F(pest duration) using FIA remeasurement cycles

	Host biomass, TgC	
Pest common name	Invaded	Uninvaded
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Fei et al. 2019

The Management of Silver Fir Forests

F. de Liocourt

Bulletin Trimestriel Société Forestière de Franche Comté et Belfort

DE L'AMÉNAGEMENT DES SAPINIÈRES

F. DE LIOCOURT, 1898

The Management of Silver Fir Forests

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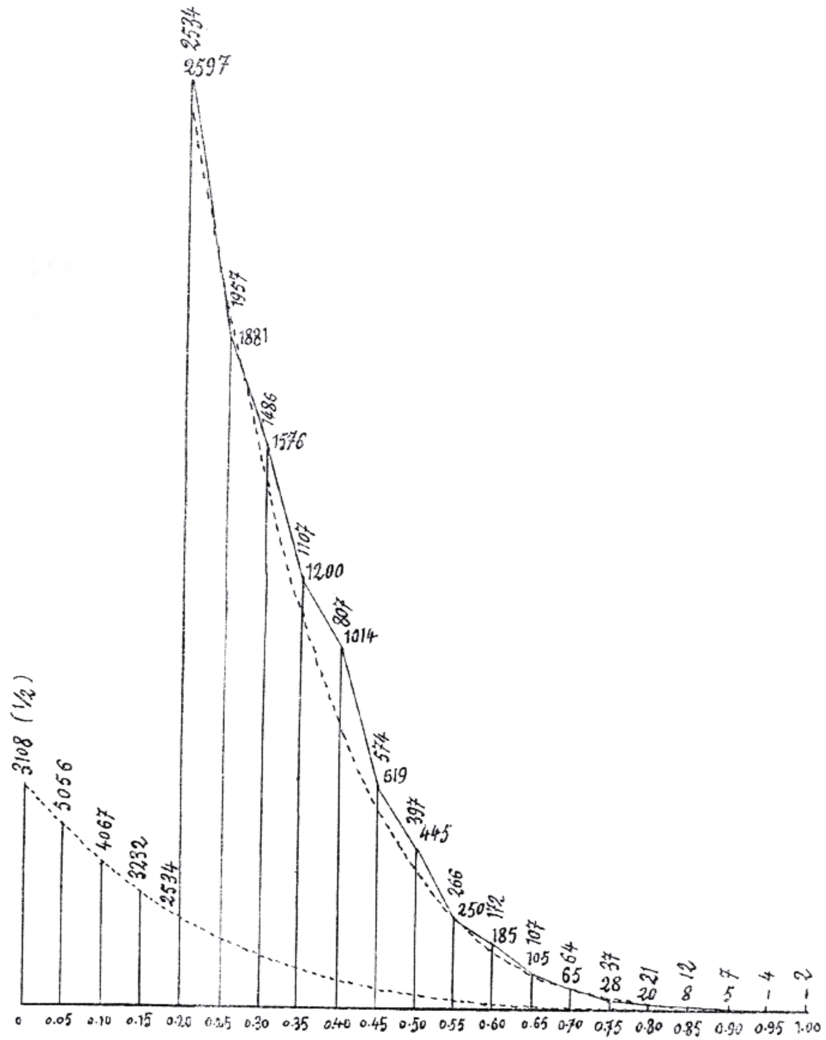
Bulletin Trimestriel Société Forestière de Franche Comté et Belfort

DE L'AMÉNAGEMENT DES SAPINIÈRES

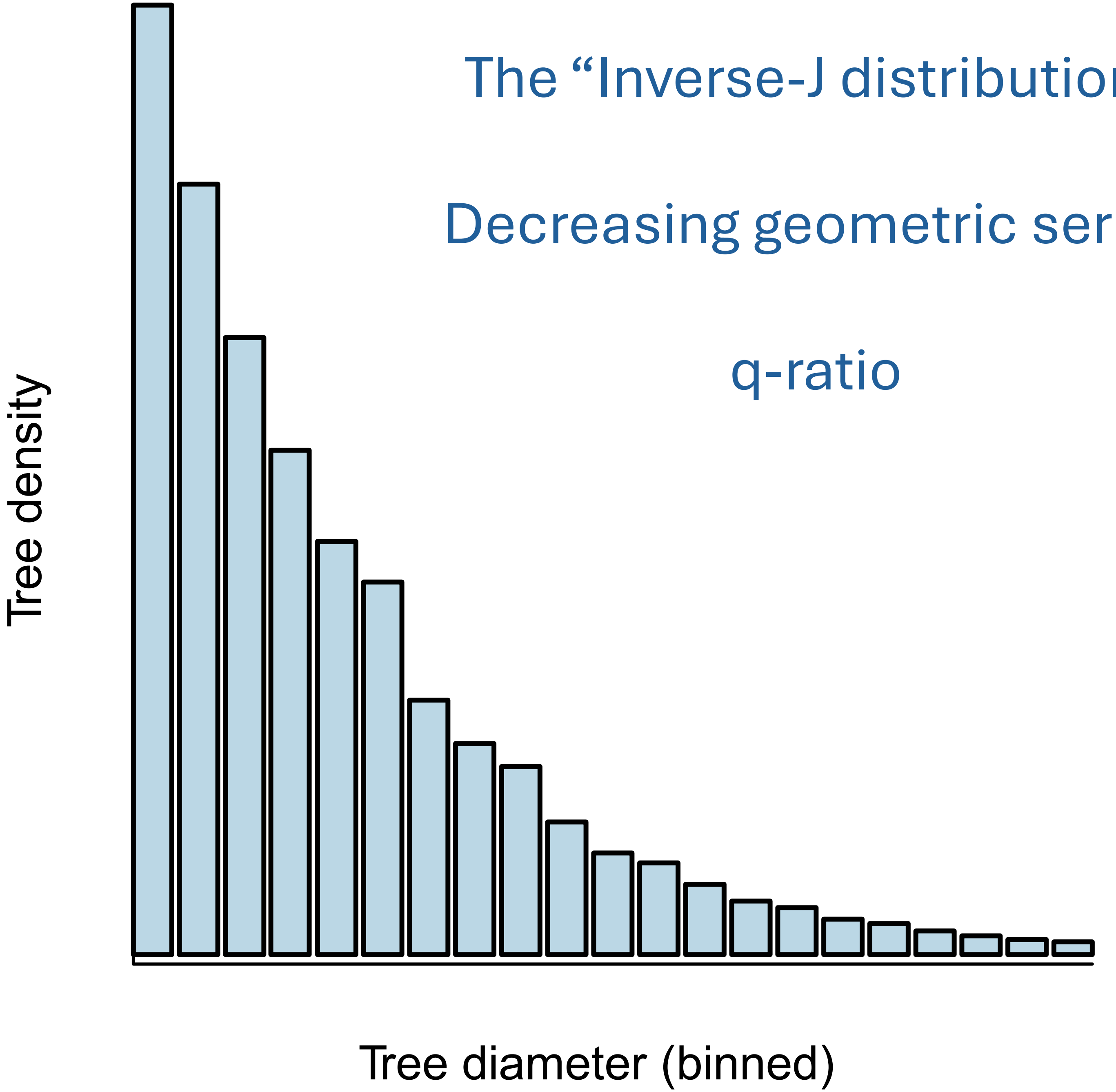
F. DE LIOCOURT, 1898



The “Inverse-J distribution”

Decreasing geometric series

q-ratio



Originally considered as a tool to guide the management of uneven aged stands

(Leak 1965, Kerr 2008; but see Ducey 2006)

Many stands (whether natural or planted) are not uneven age

Old growth red pine near Itasca, MN, *Pinus resinosa*

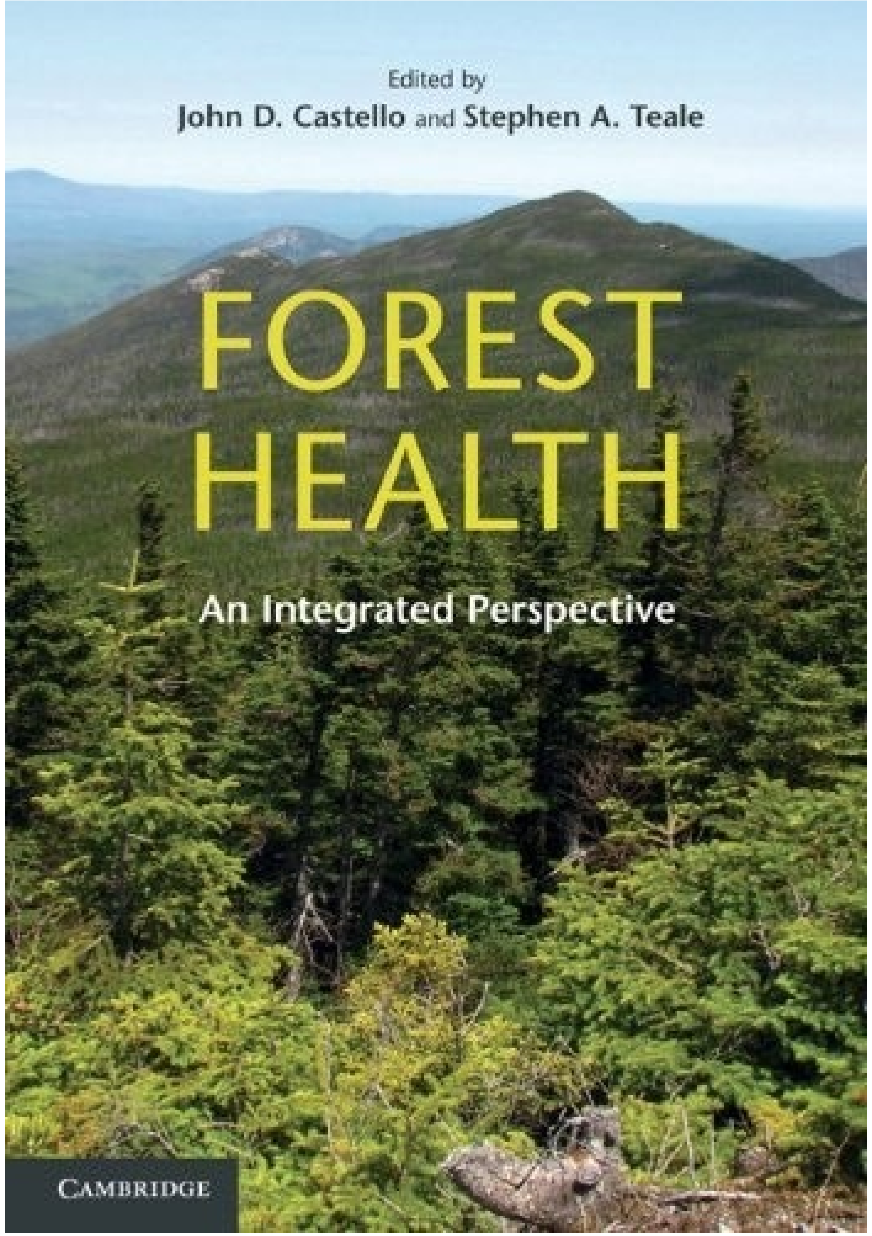
Many stands (whether natural or planted) are not uneven age

Beech thicket (aka “beech hell”) in New Hampshire, USA

Stand and landscape analysis of forest health

Stand/forest structure and composition can tell us a lot about the TRAJECTORY of the forest

How can we best use these concepts to understand and predict key aspects of forest health, standing biomass, and carbon sequestration potential?



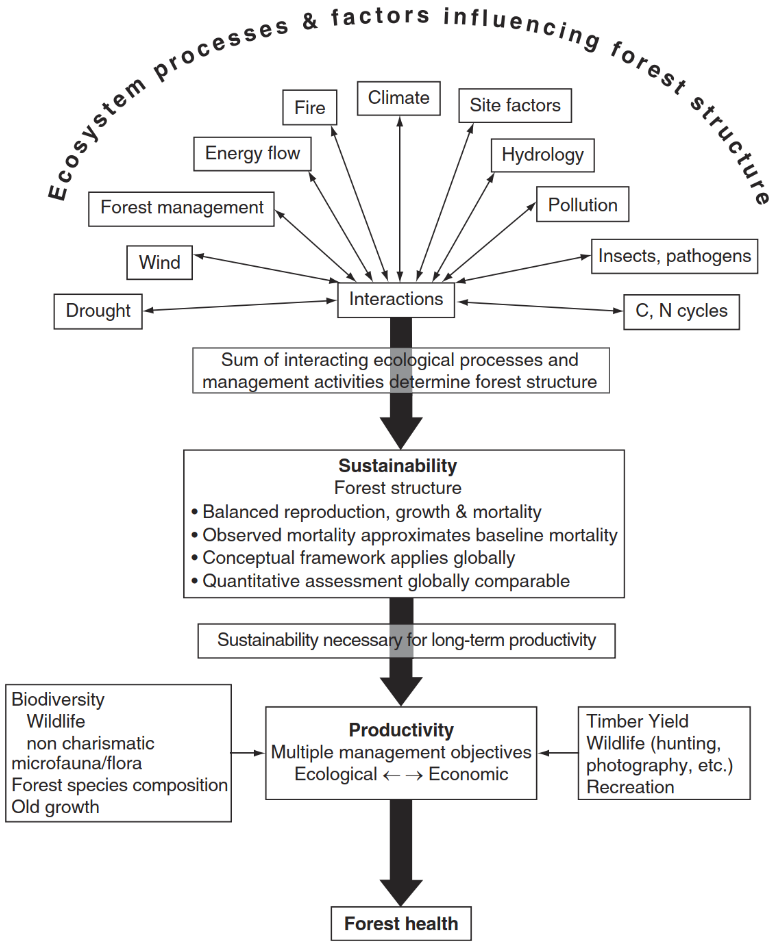
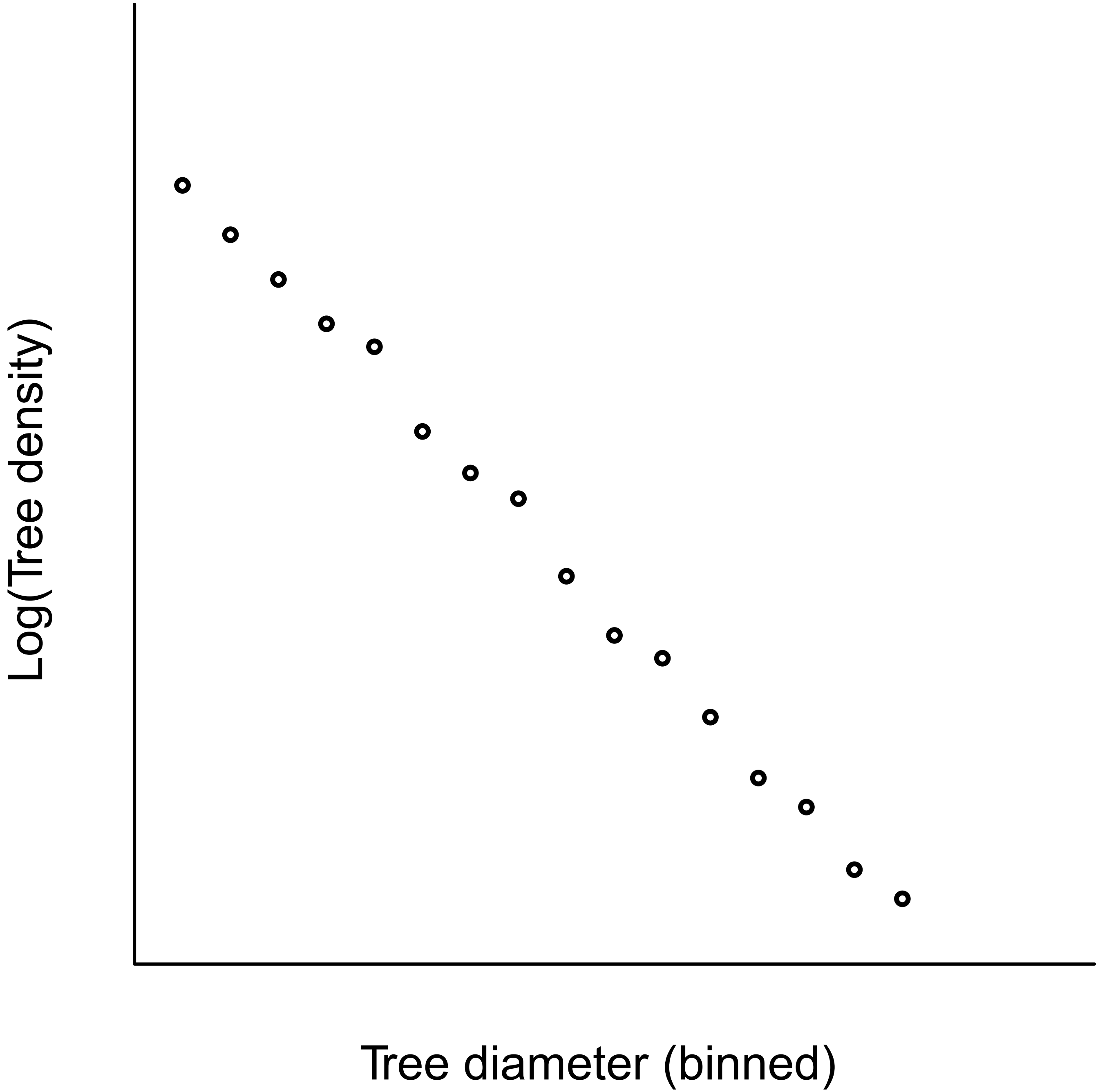
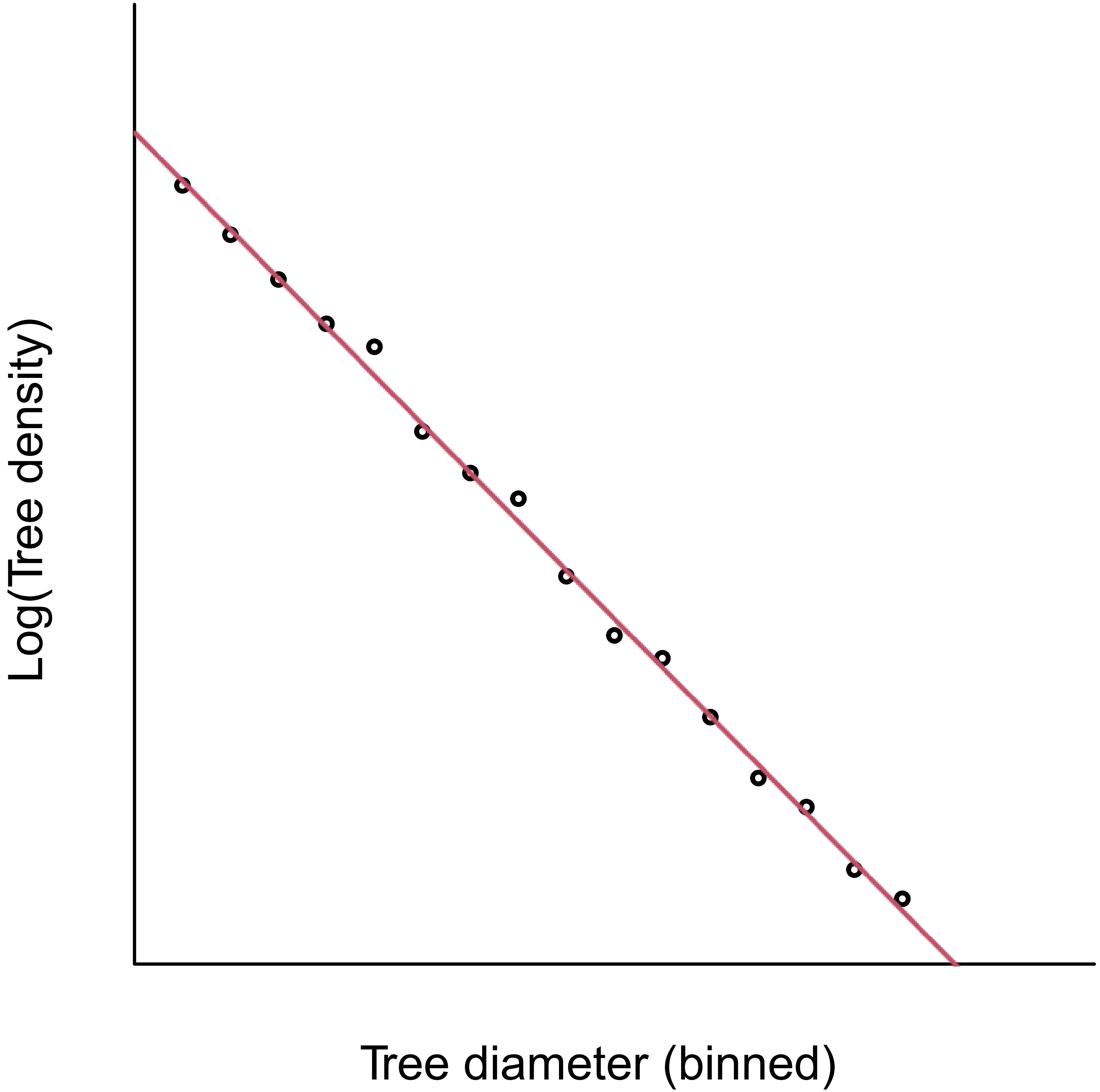
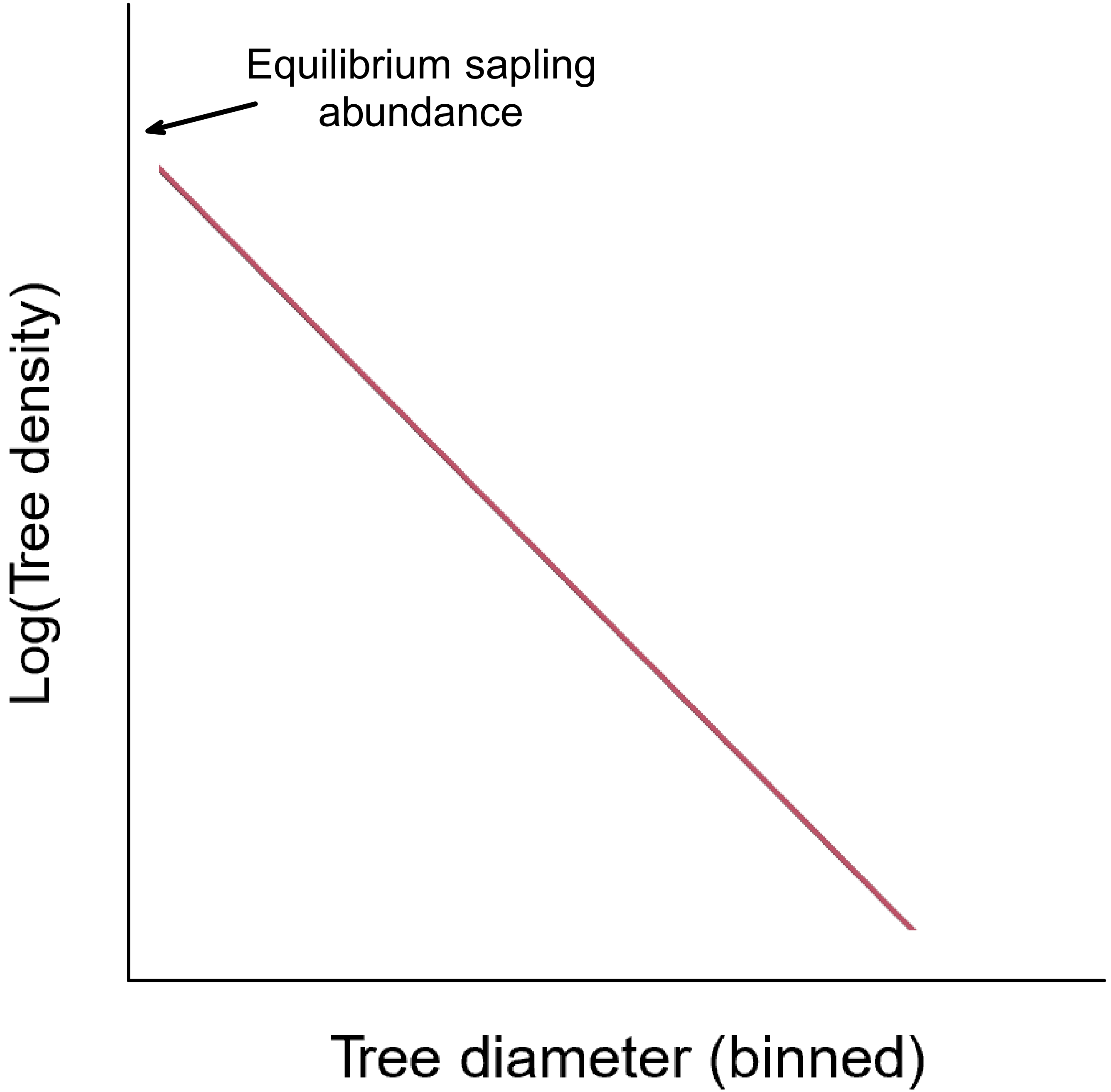
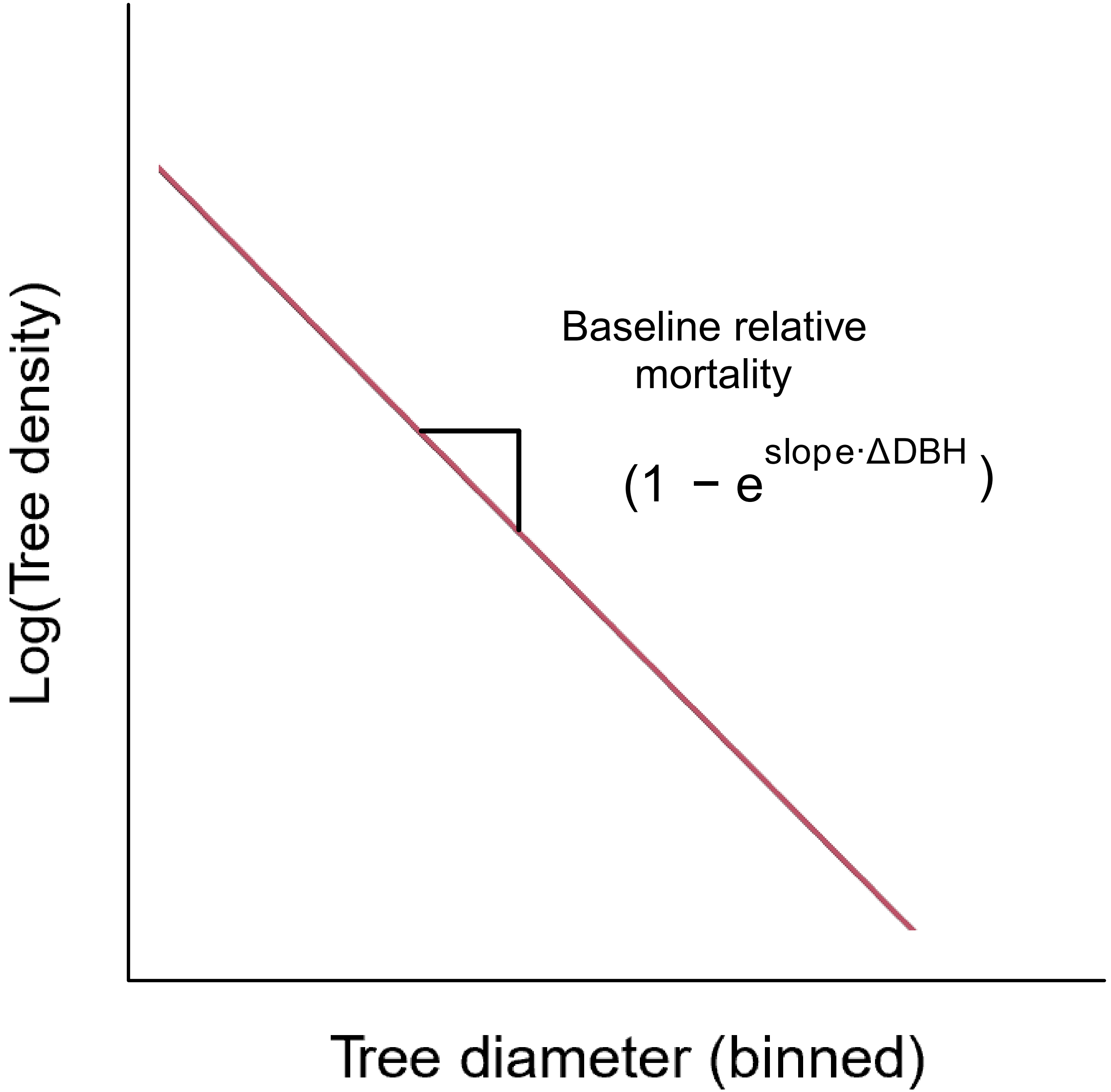


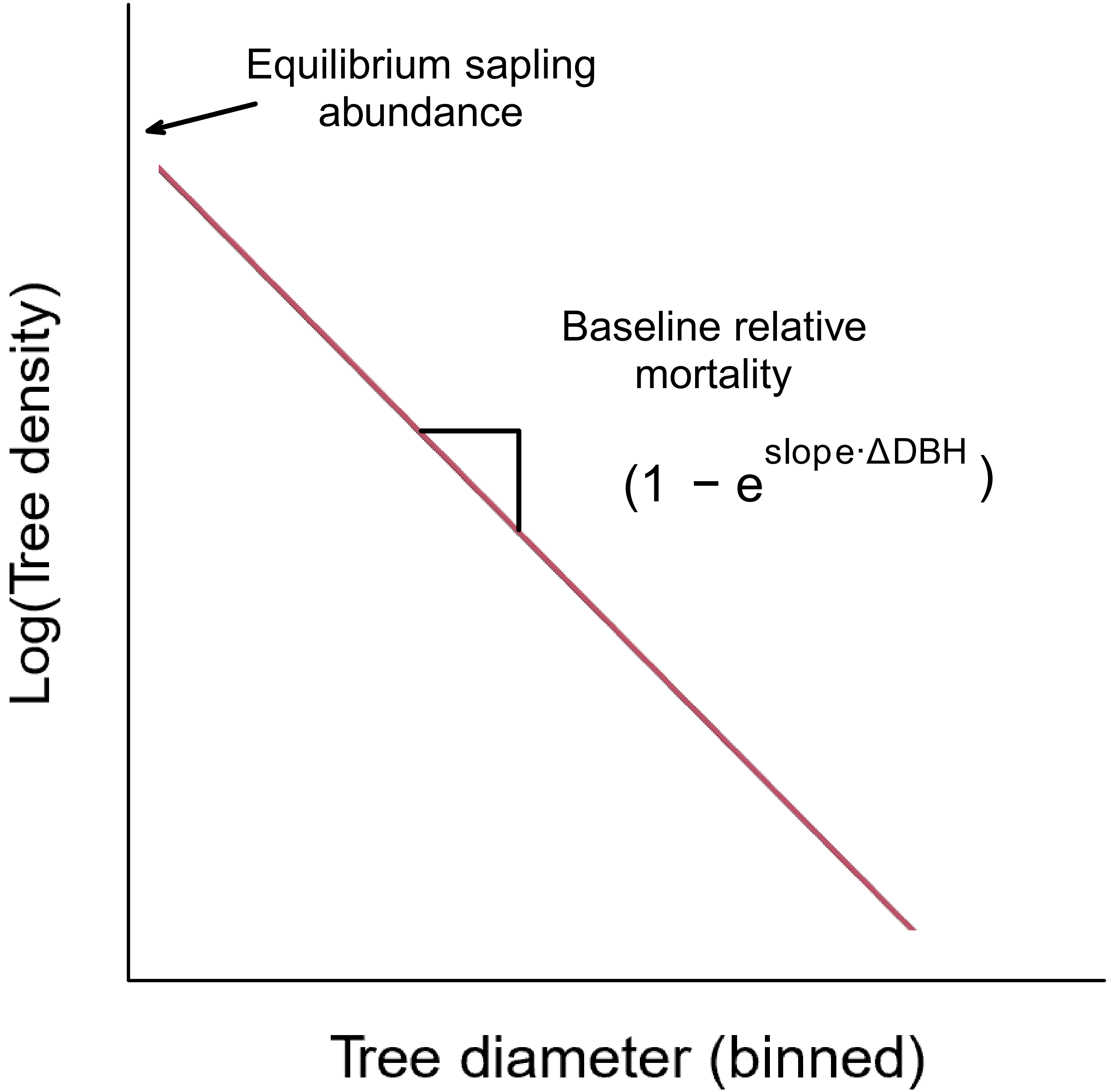
Figure 1.5 Relationships among interacting ecological factors, management, forest structure and sustainability, and productivity.

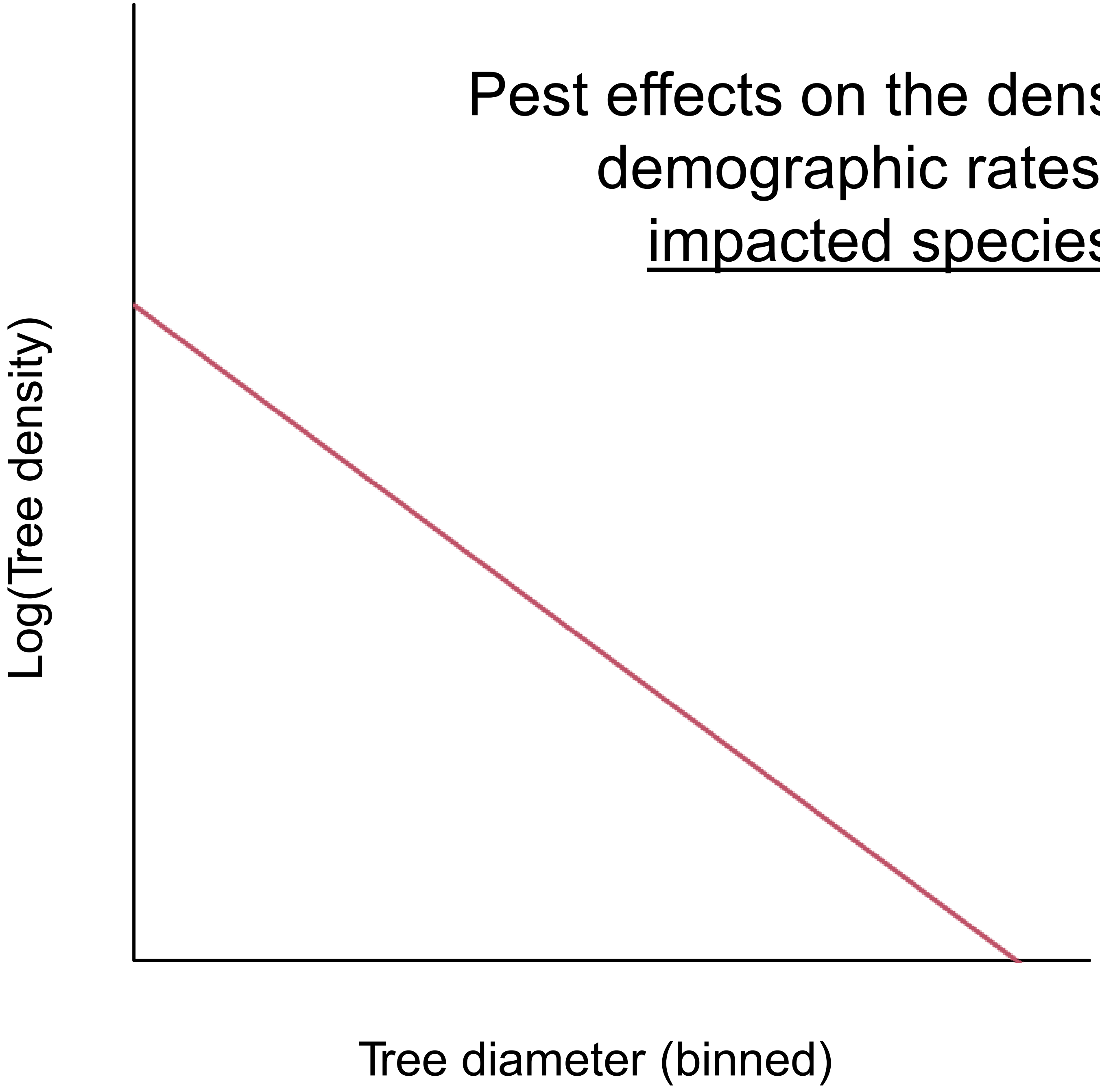

Log(Tree density)
Tree diameter (binned)

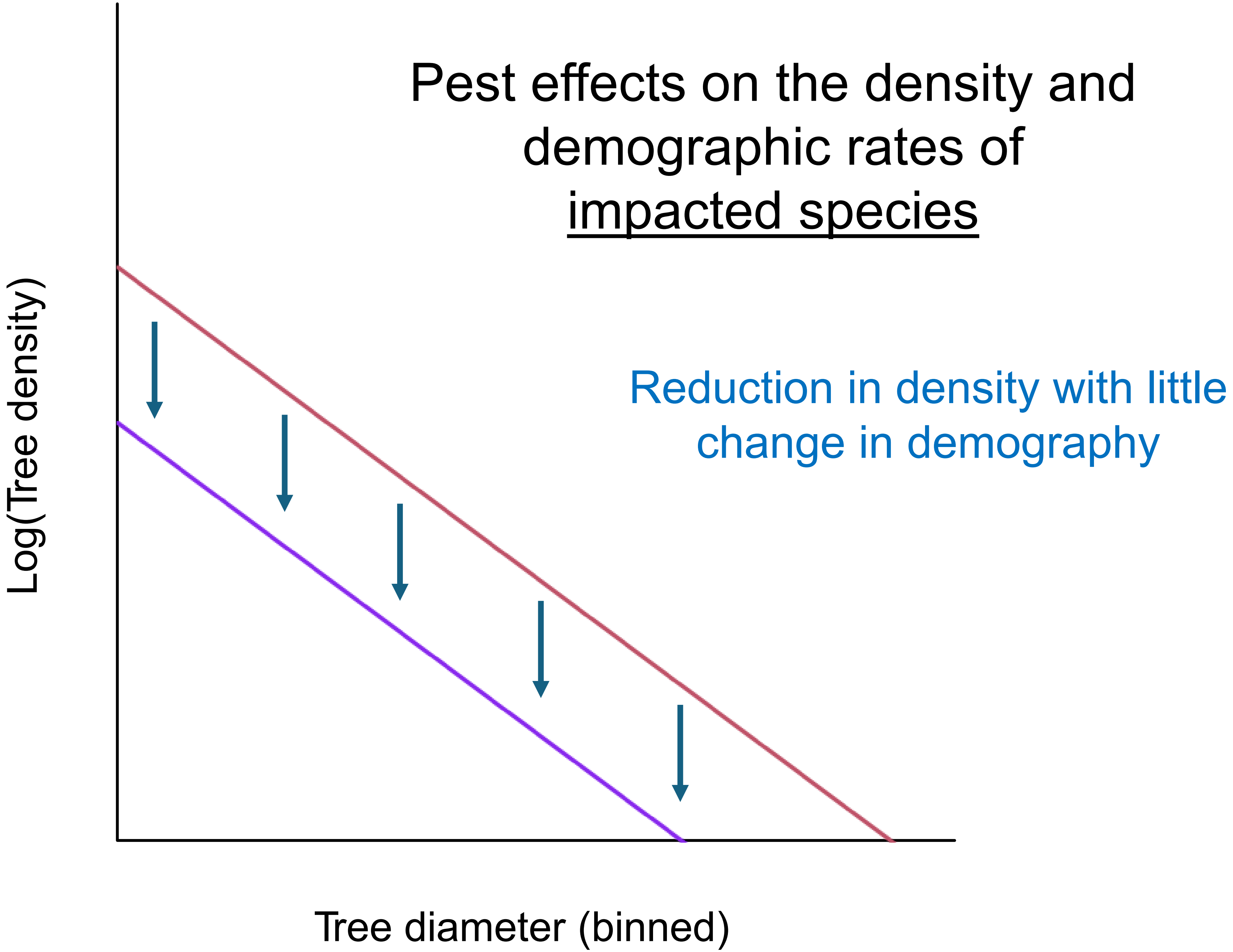

Log(Tree density)
Tree diameter (binned)

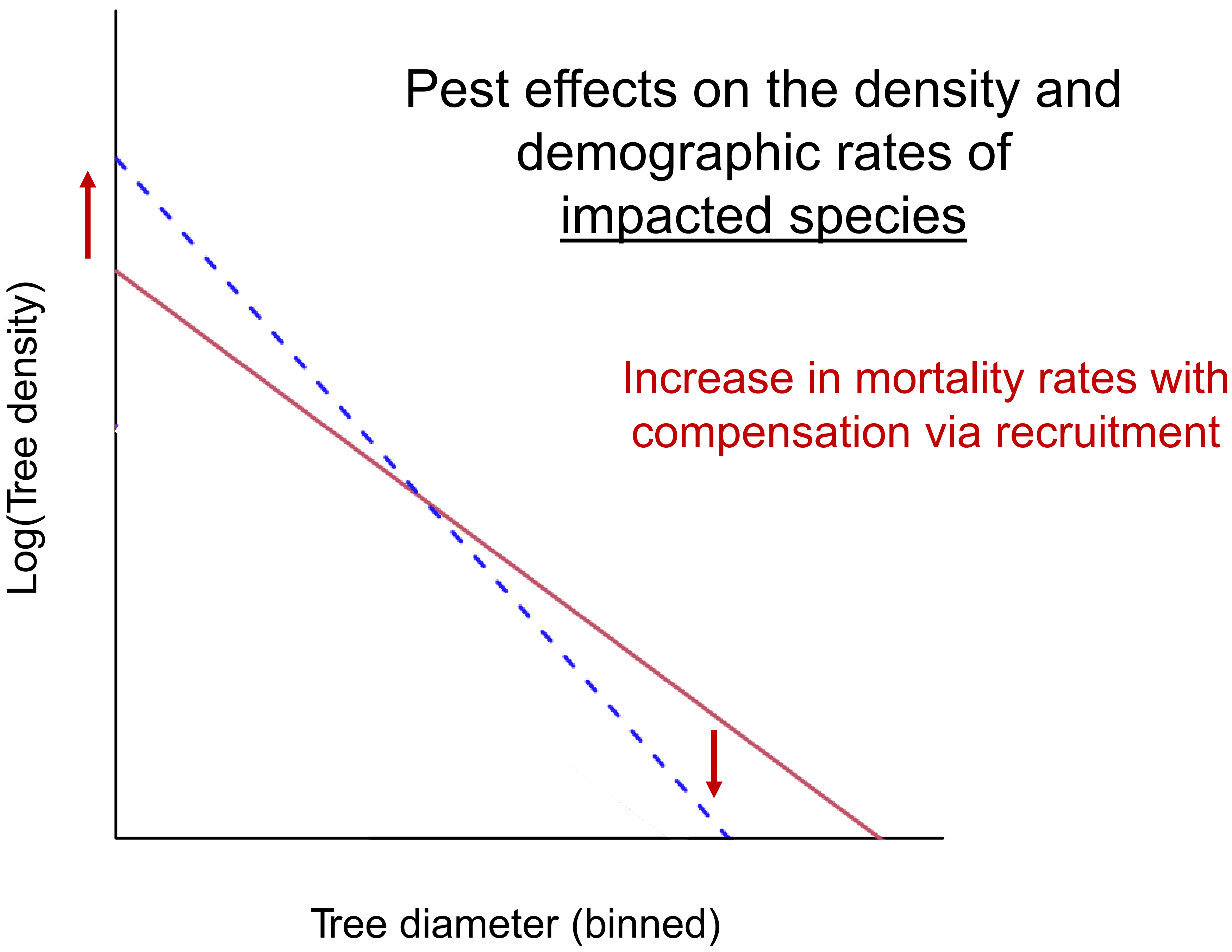

Equilibrium sapling abundance
Log(Tree density)
Tree diameter (binned)


Log(Tree density)
Baseline relative mortality
(1 − e^slope·ΔDBH)
Tree diameter (binned)

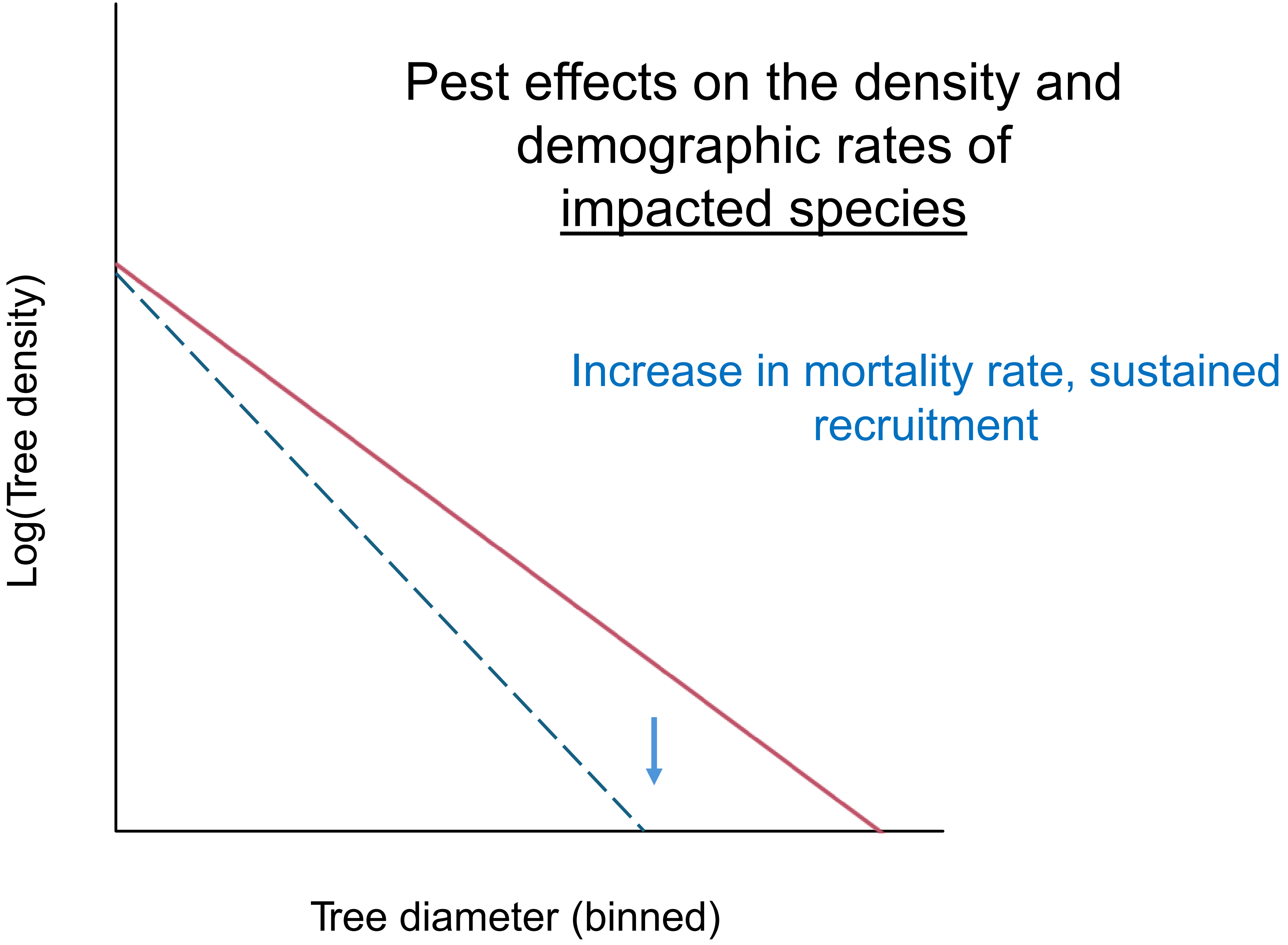

Equilibrium sapling abundance
Baseline relative mortality
$(1 - e^{slope \cdot \Delta DBH})$
Log(Tree density)
Tree diameter (binned)


Pest effects on the density and
demographic rates of
impacted species
Log(Tree density)
Tree diameter (binned)

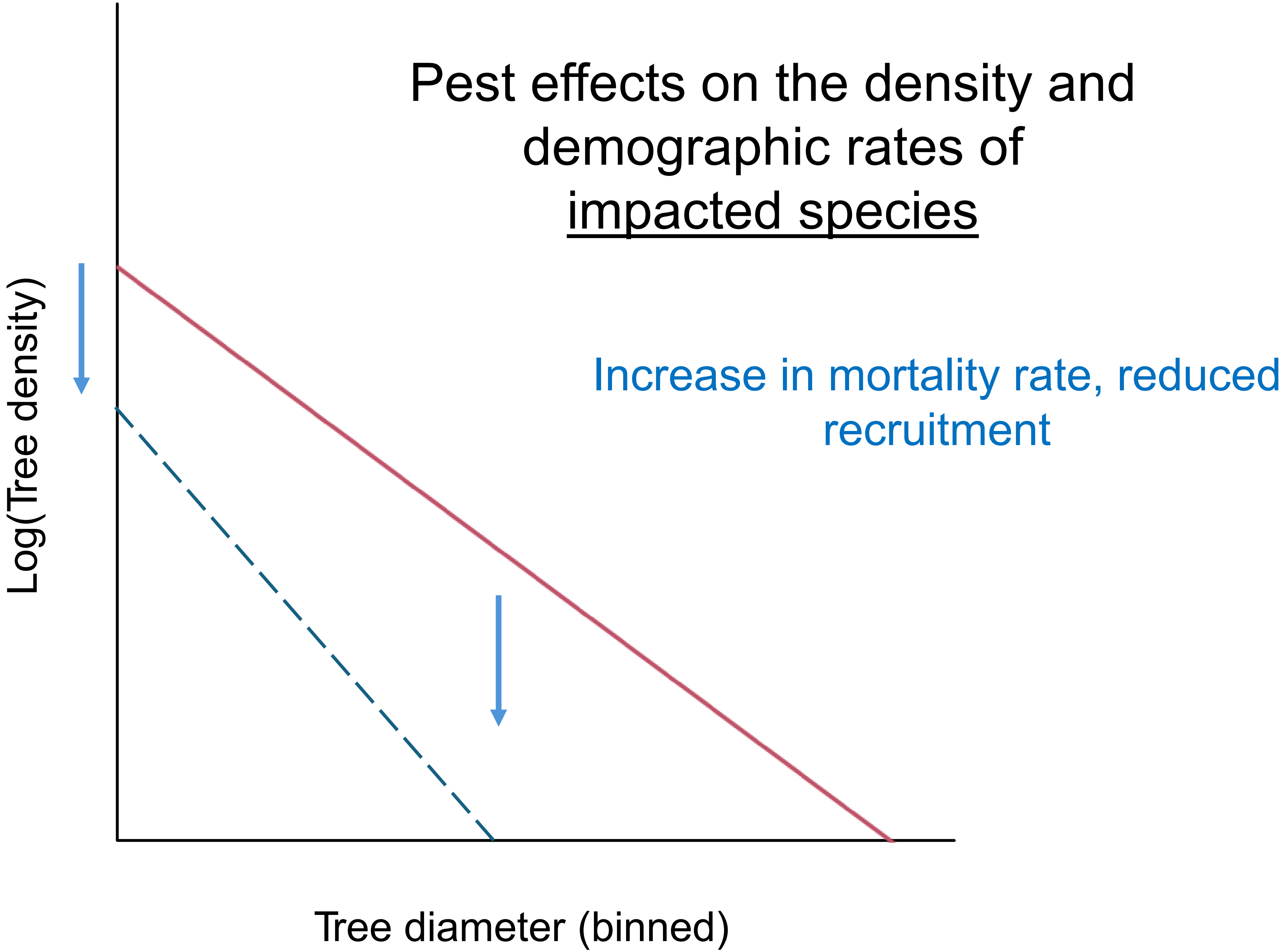

Pest effects on the density and
demographic rates of
impacted species
Reduction in density with little
change in demography
Log(Tree density)
Tree diameter (binned)


Pest effects on the density and
demographic rates of
impacted species
Increase in mortality rates with
compensation via recruitment
Log(Tree density)
Tree diameter (binned)

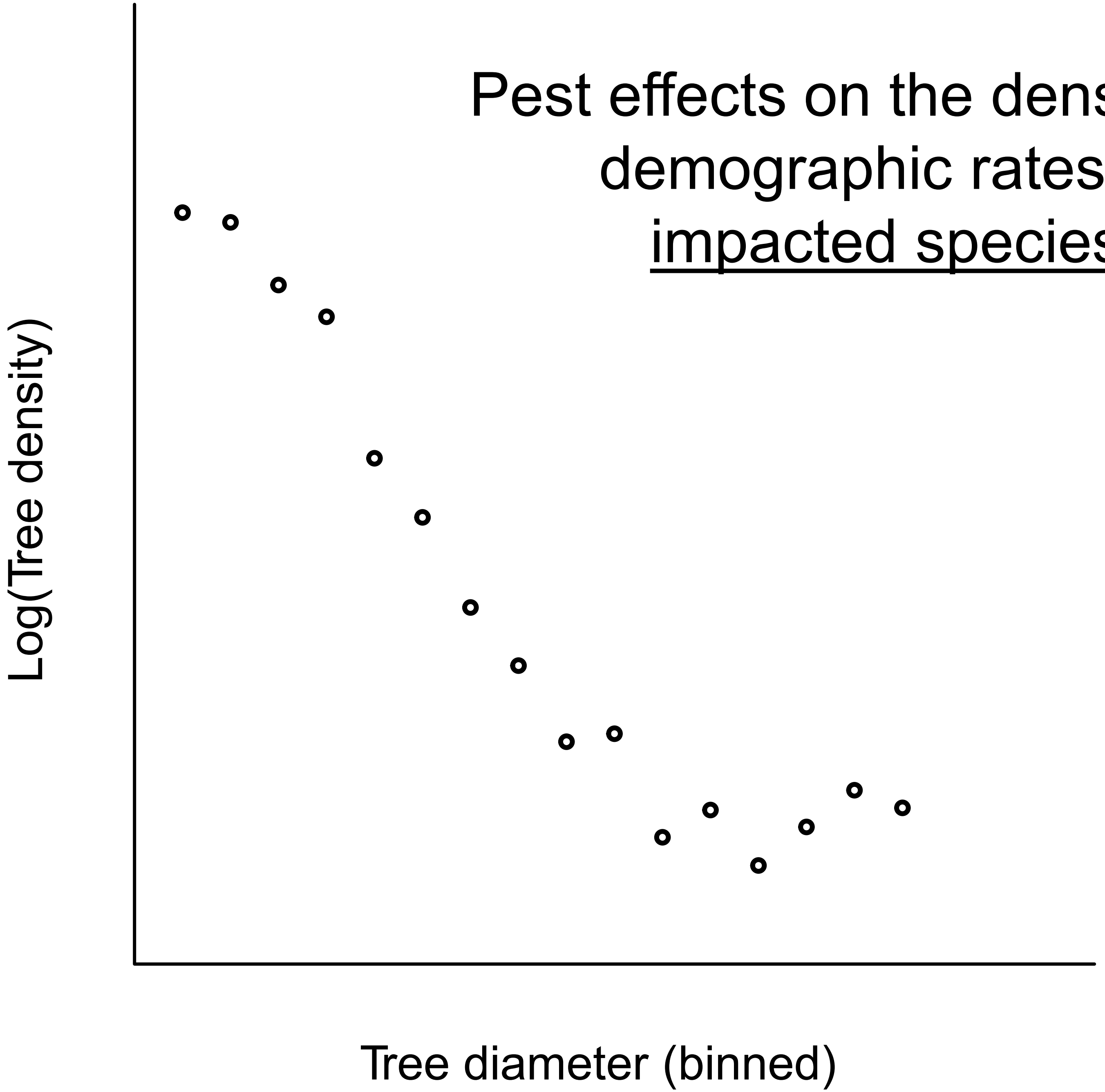
Pest effects on the density and demographic rates of <u>impacted species</u>

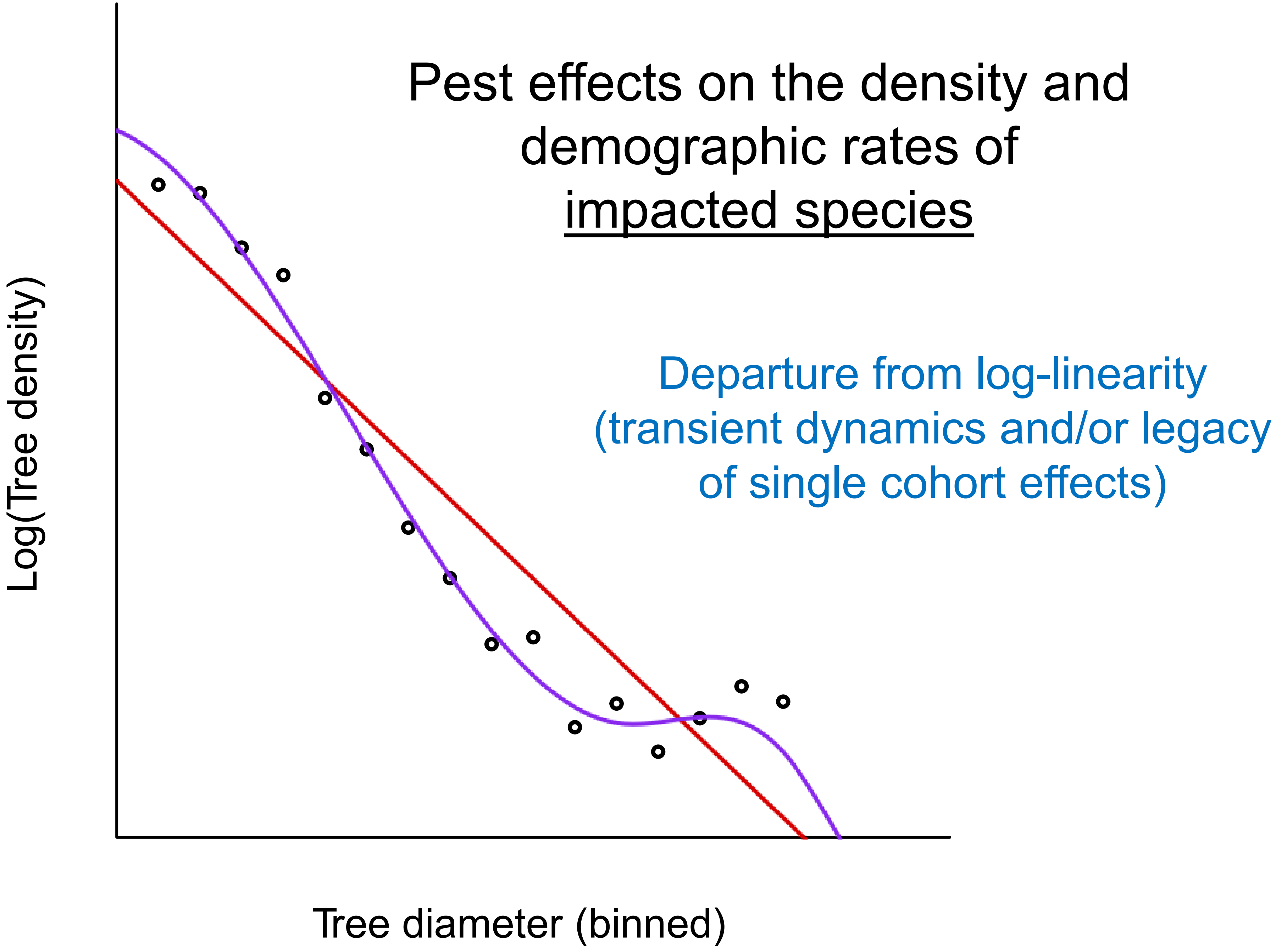


Pest effects on the density and demographic rates of <u>impacted species</u>

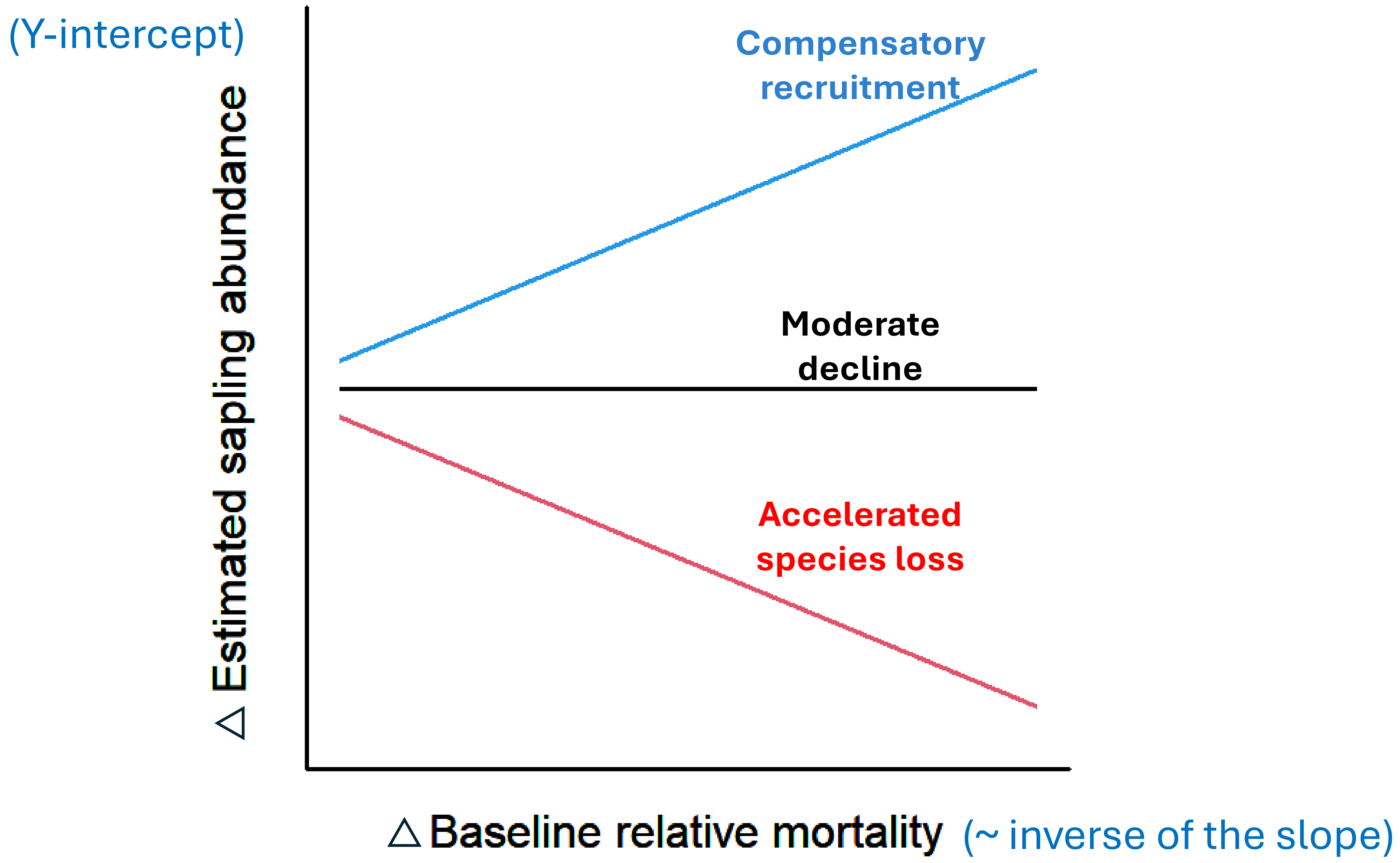


Pest effects on the density and demographic rates of <u>impacted species</u>

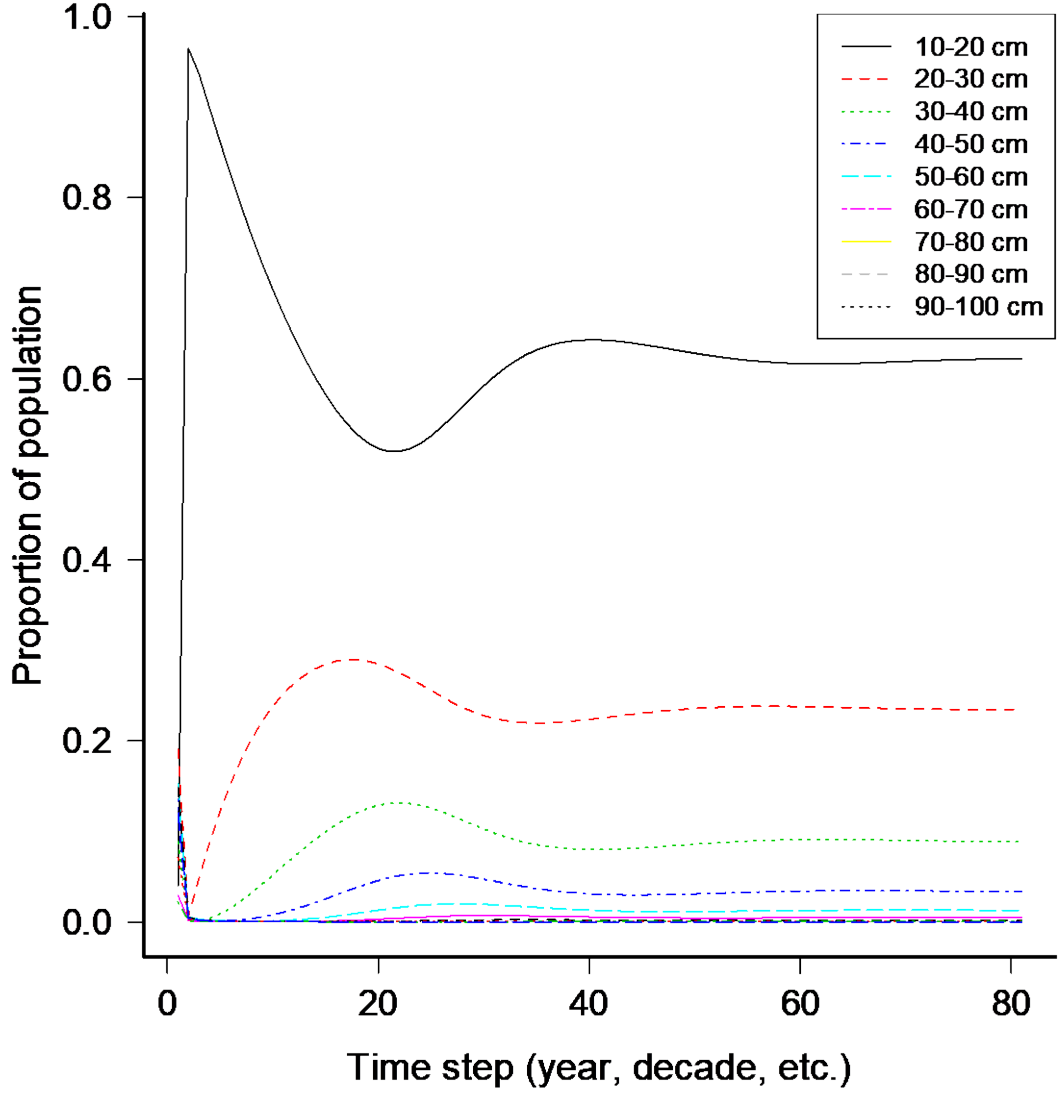




Pest effects on the density and demographic rates of impacted species
Departure from log-linearity (transient dynamics and/or legacy of single cohort effects)
Log(Tree density)
Tree diameter (binned)

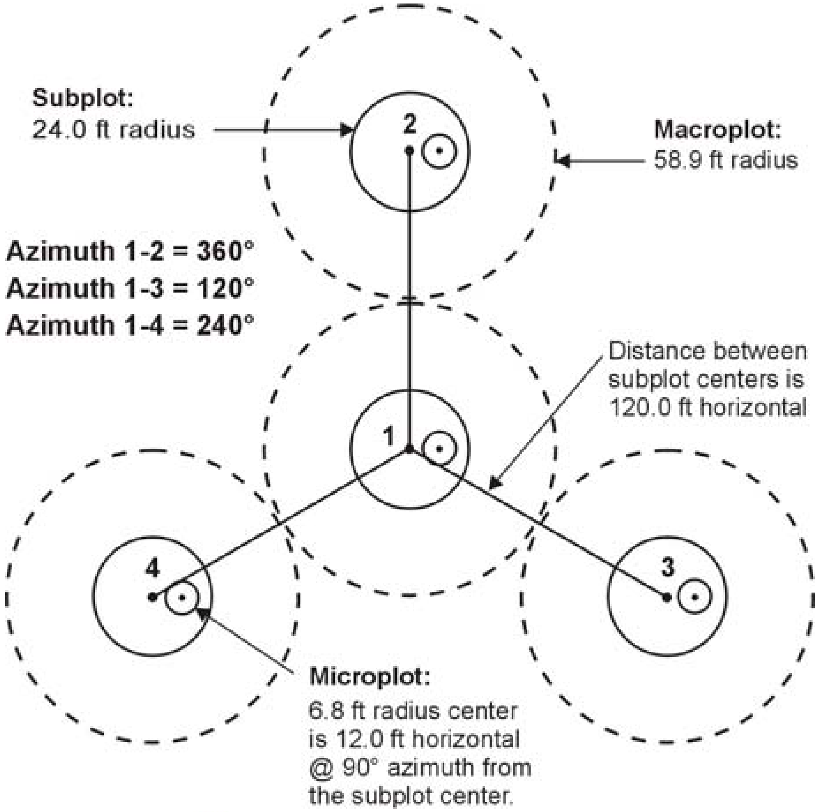

(Y-intercept)
Compensatory recruitment
Moderate decline
Accelerated species loss
△ Estimated sapling abundance
△ Baseline relative mortality
(~ inverse of the slope)

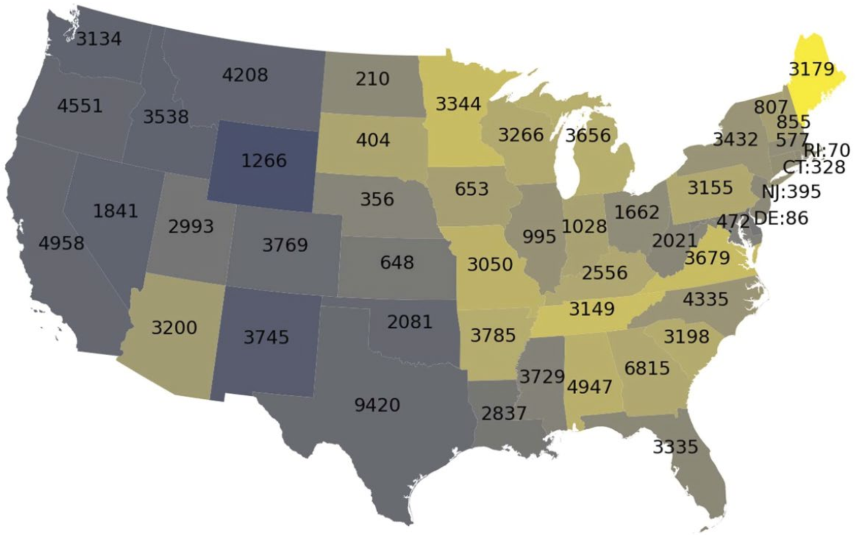
Does size structure at the forest scale <u>approximate</u> equilibrium?



Forest Inventory and Analysis (FIA)

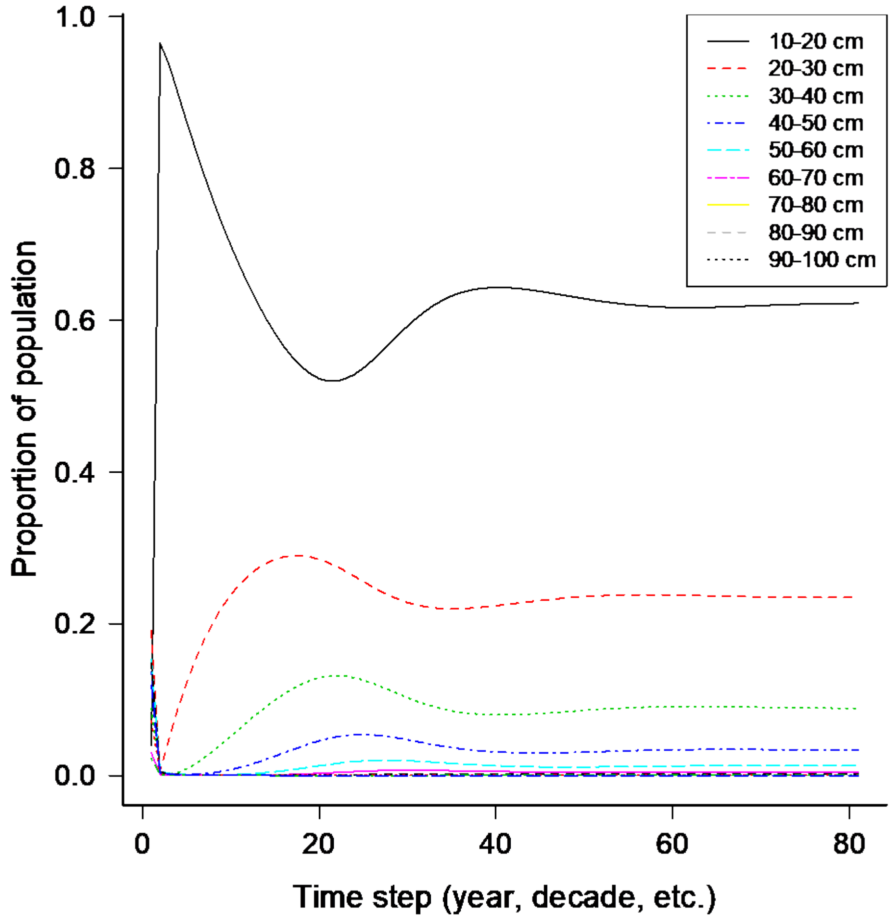
- 1-acre sample area for every 6,000 acres of forest
  - (~127 000 plots total)
- Remeasured ~ 20% per year

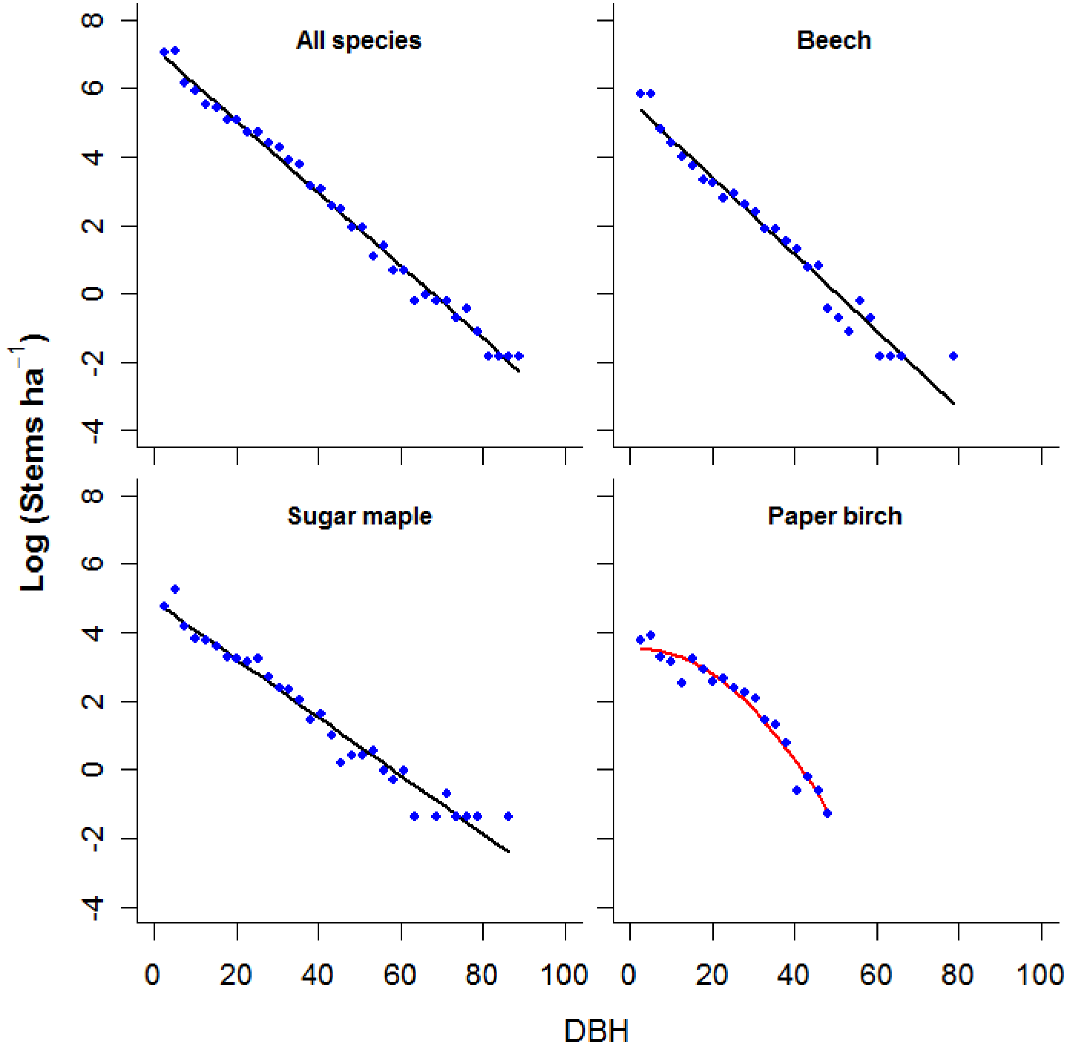




Does size structure at the forest scale approximate equilibrium?

- Roughly speaking, yes …



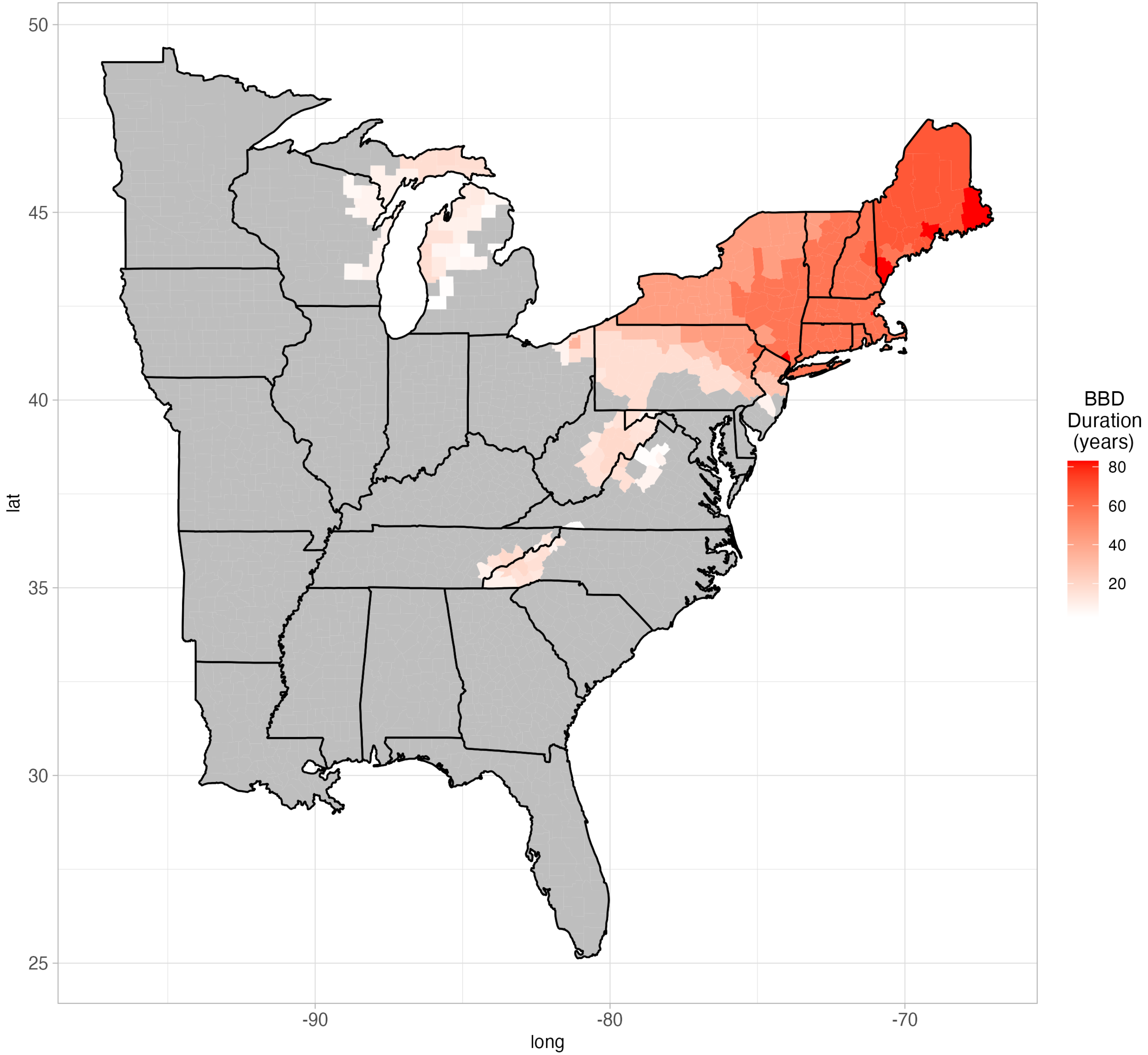


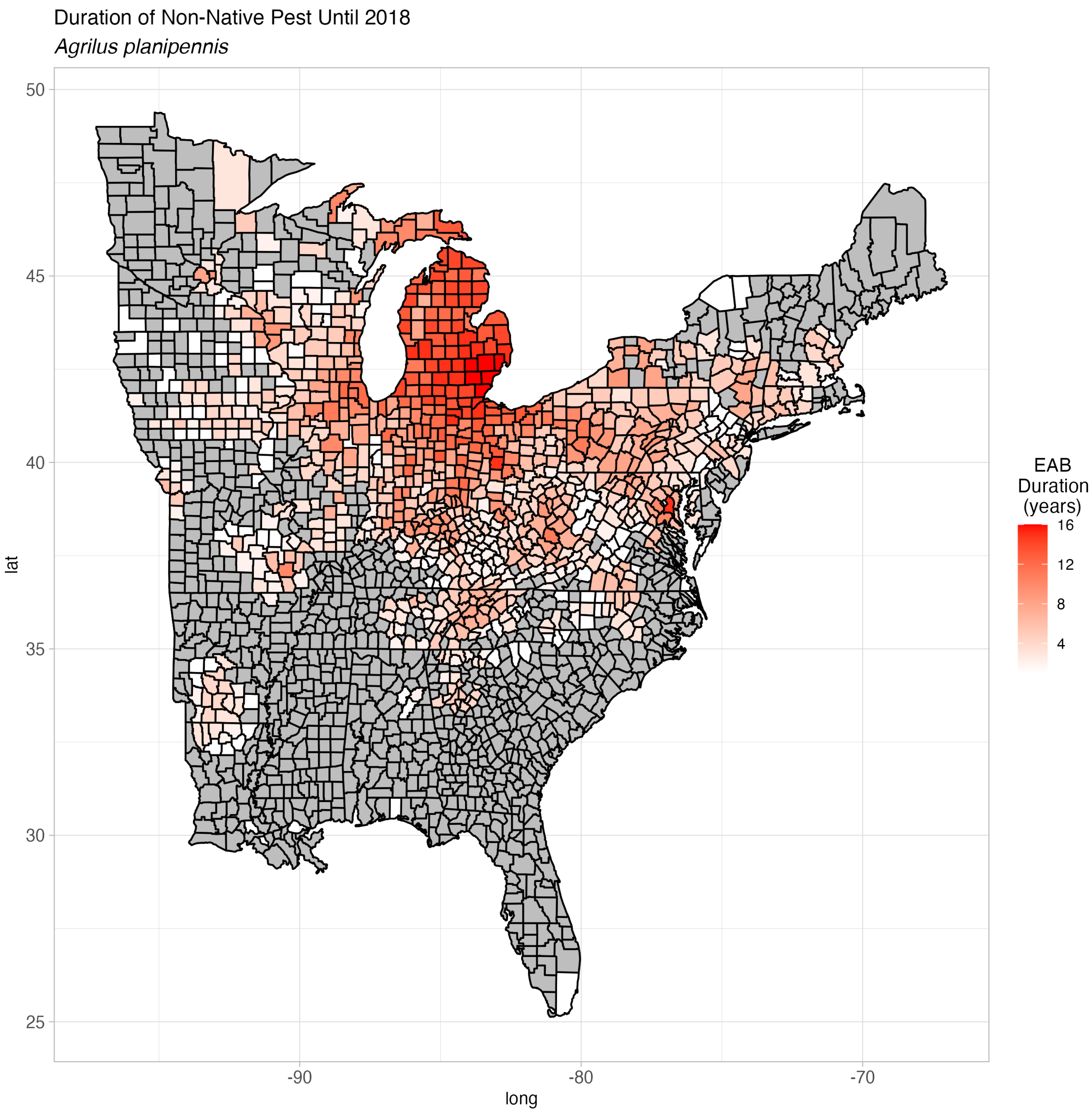
Does size structure at the forest scale approximate equilibrium?

- **Roughly speaking, yes … but**

Do empirical measures of mortality and in-growth (derived from FIA remeasurement data) match expectations based on structural equilibrium?

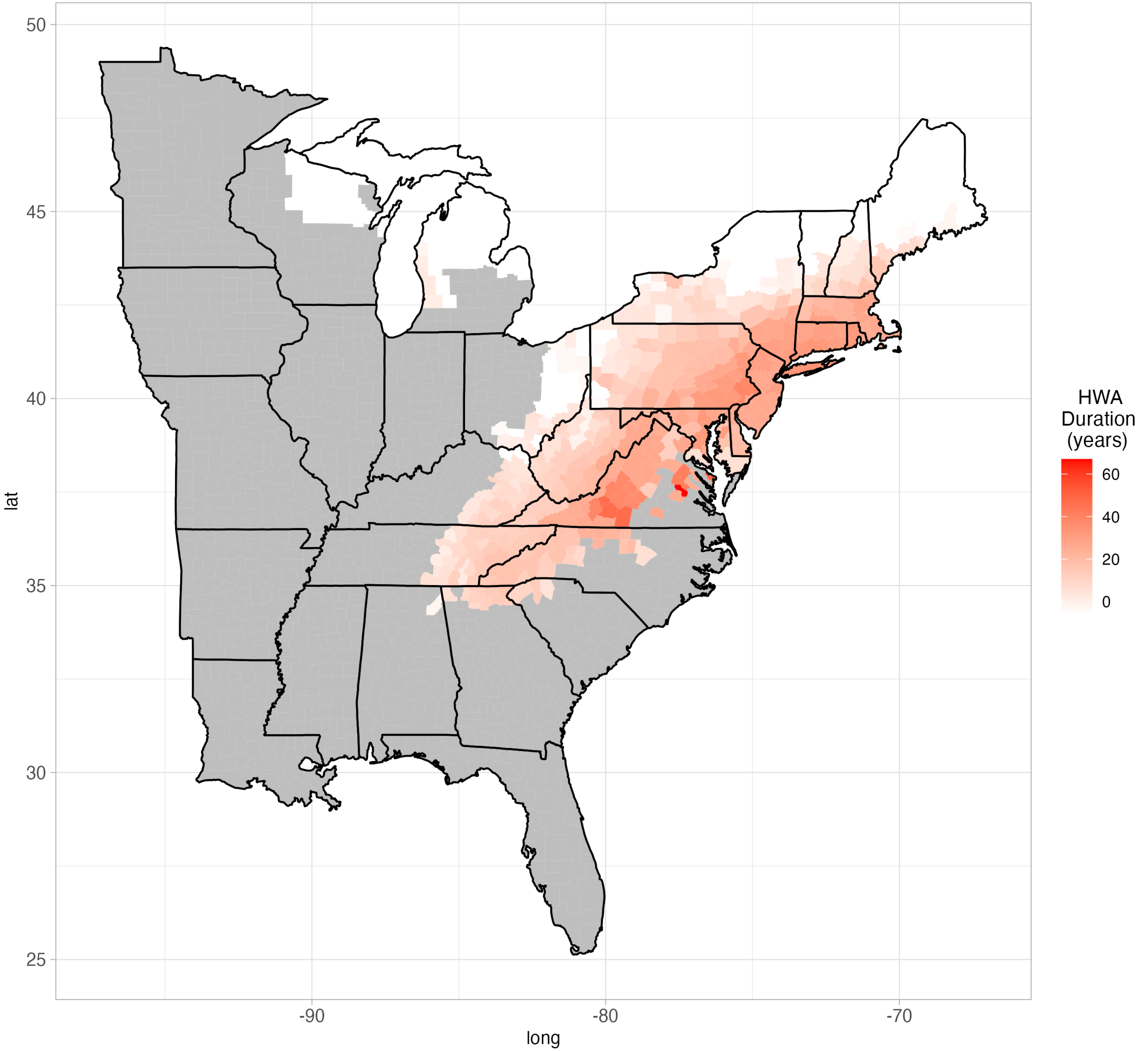
Duration of Non-Native Pest Until 2018
Cryptococcus fagisuga

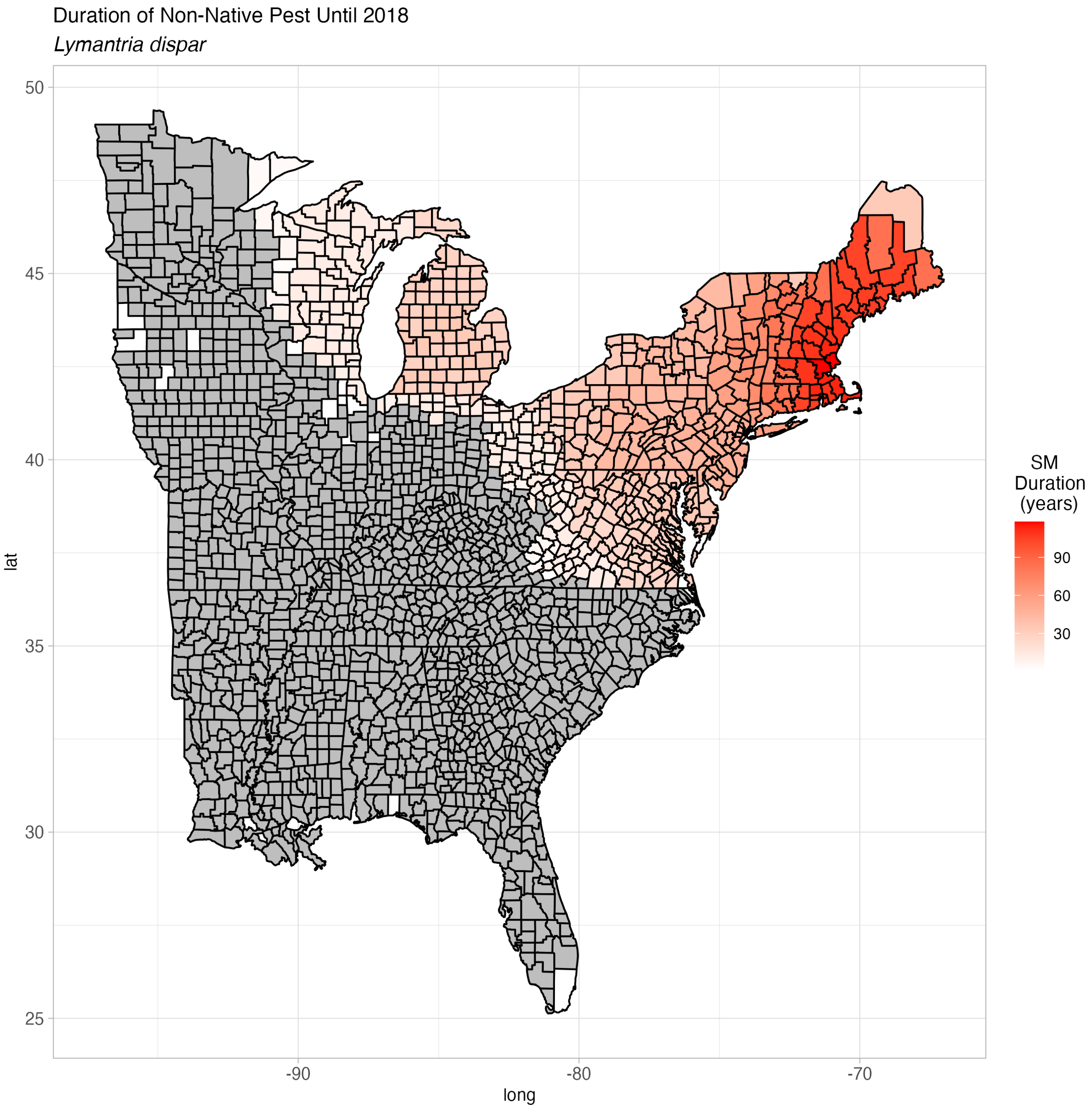




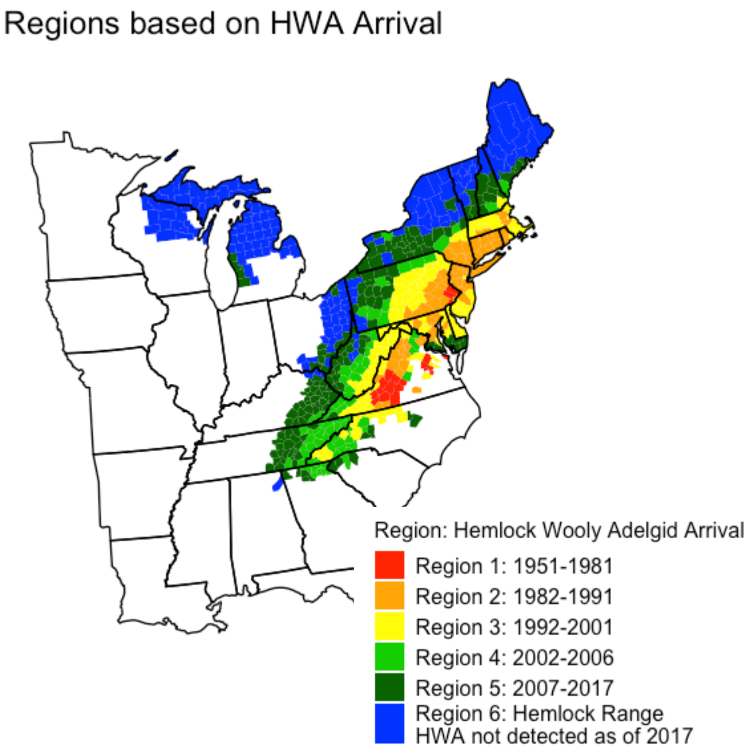
Duration of Non-Native Pest Until 2018
Agrilus planipennis
lat
long
50
45
40
35
30
25
-90
-80
-70
EAB
Duration
(years)
16
12
8
4

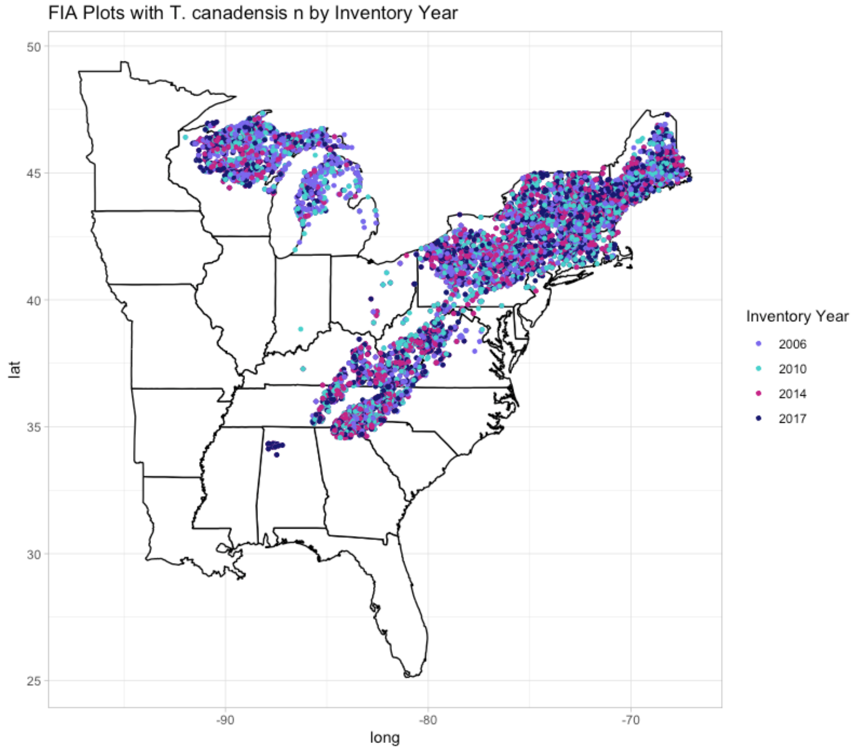
Duration of Non-Native Pest Until 2018
Adelges tsugae

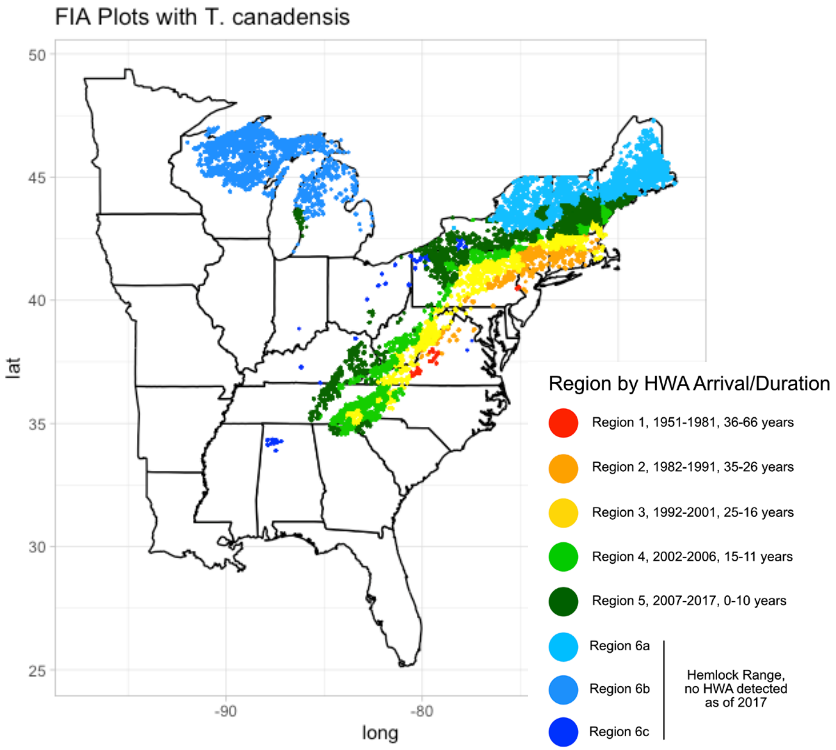



Duration of Non-Native Pest Until 2018
Lymantria dispar
lat
long
50
45
40
35
30
25
-90
-80
-70
SM
Duration
(years)
90
60
30

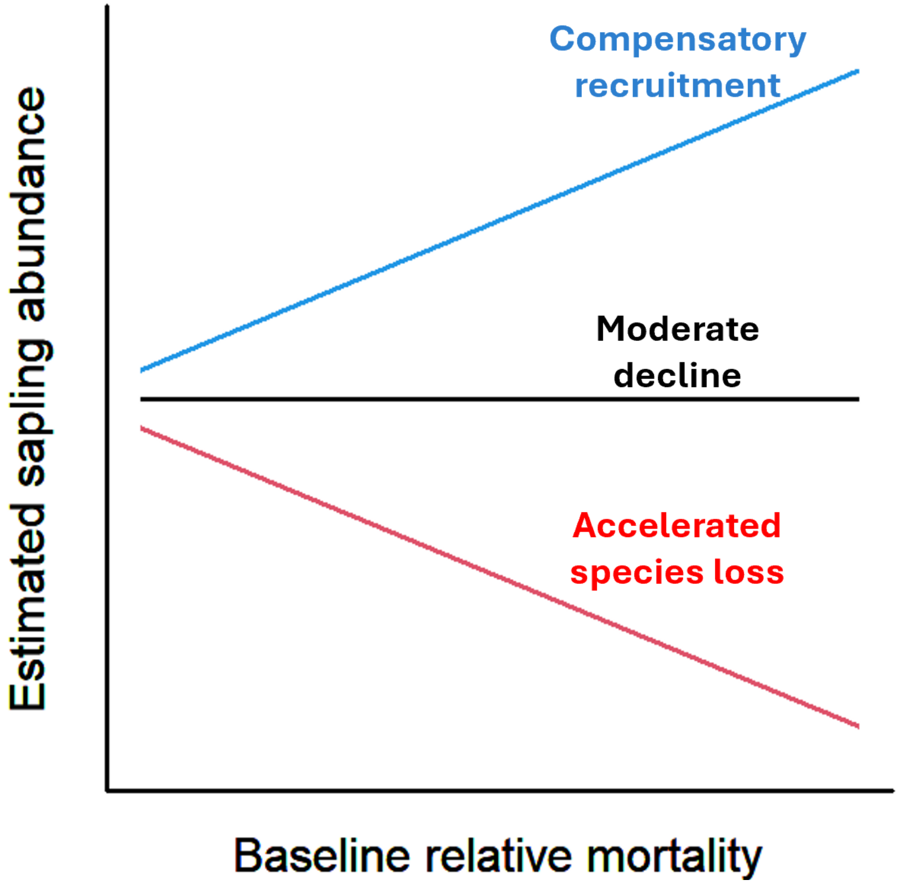
Aggregation methods (county v. region?)

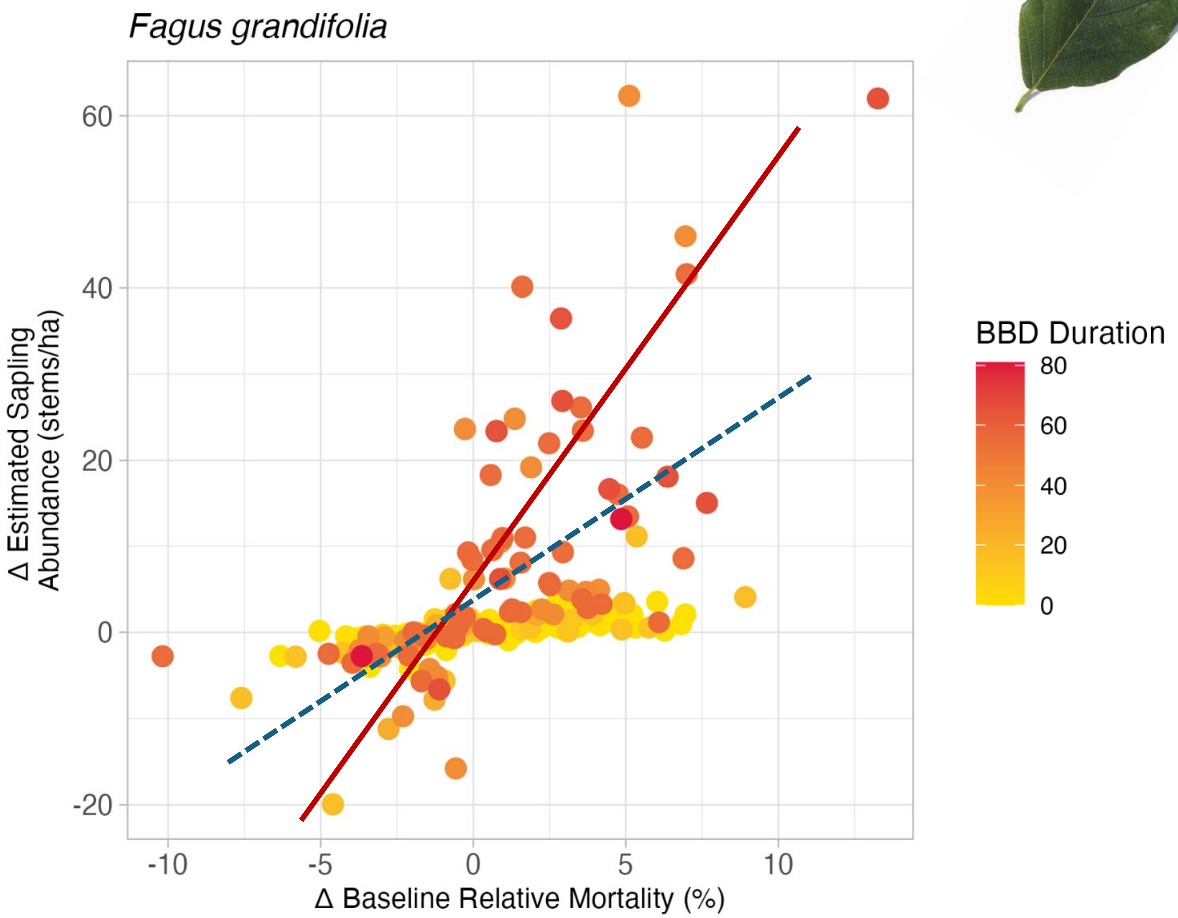




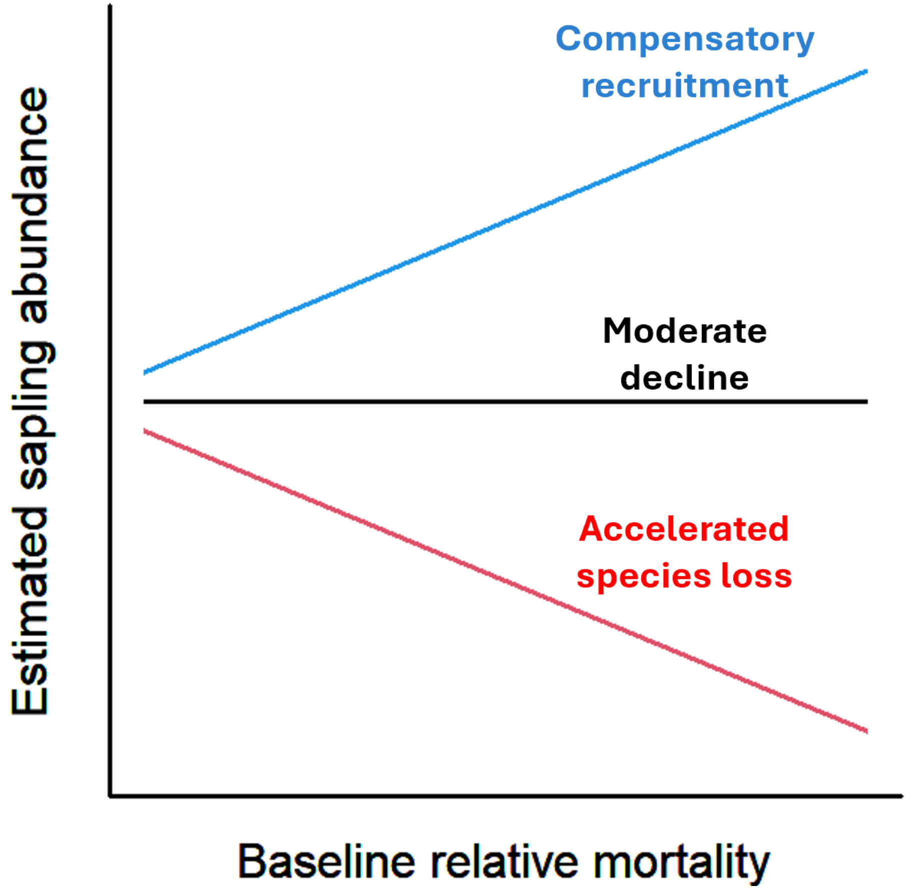


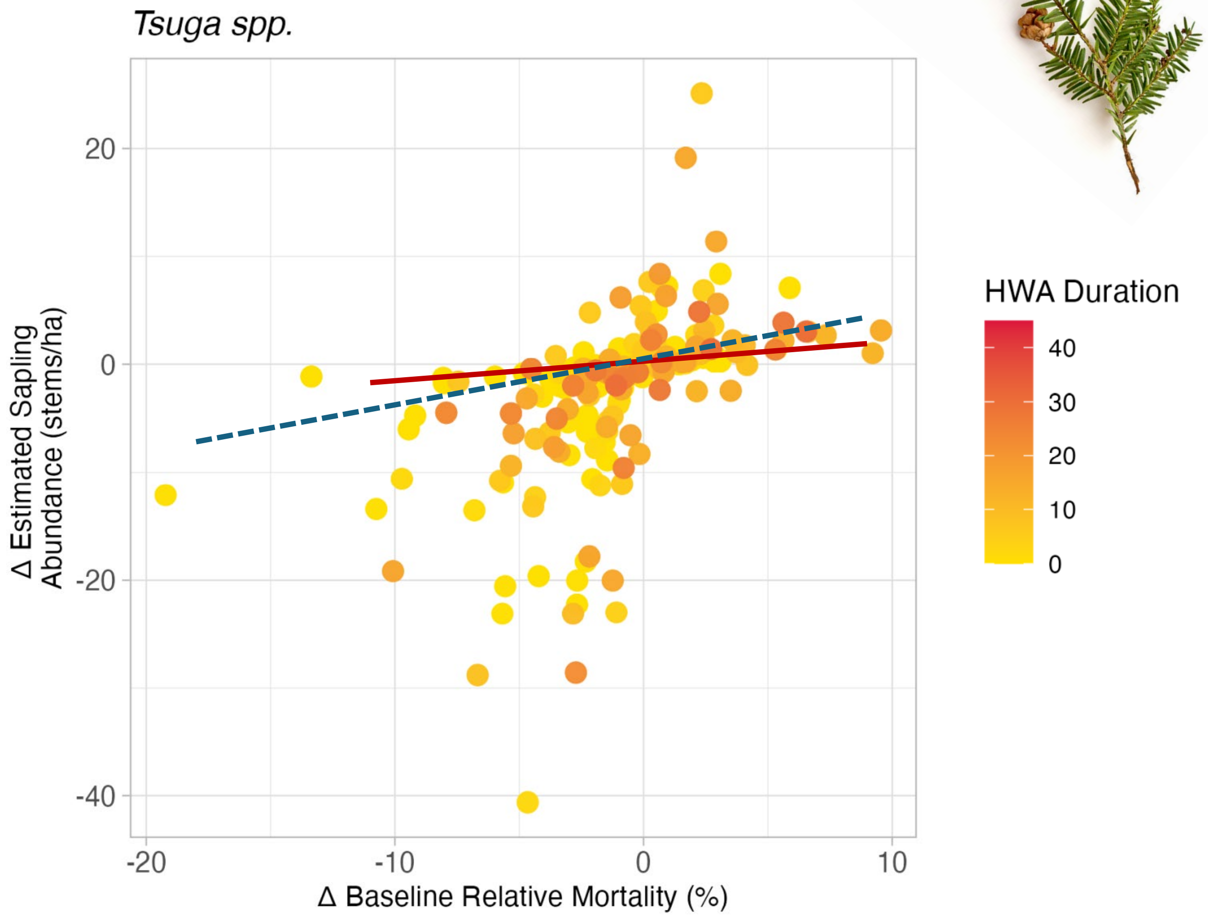
American beech (co-variance in de Liocourt parameters)

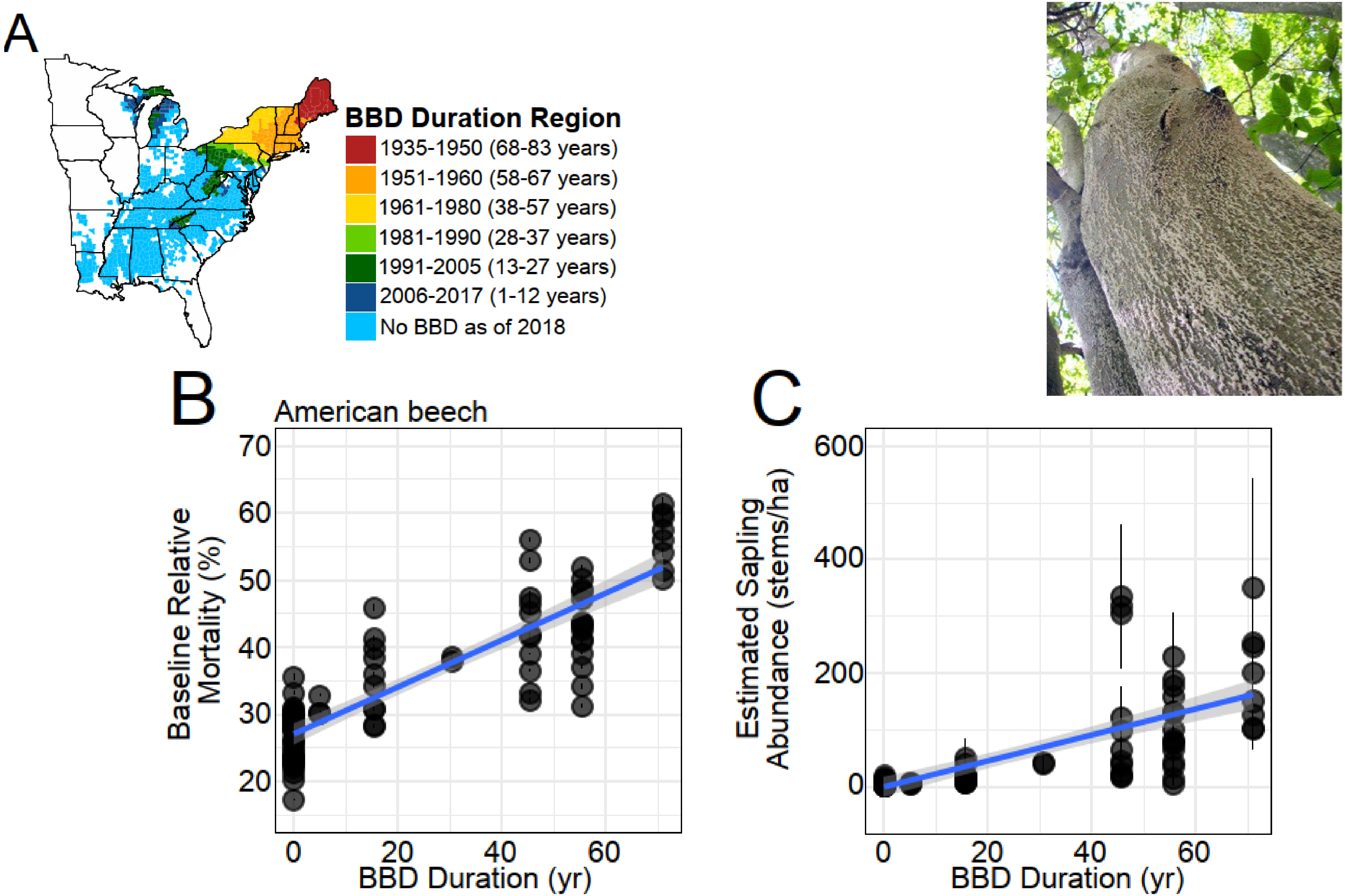


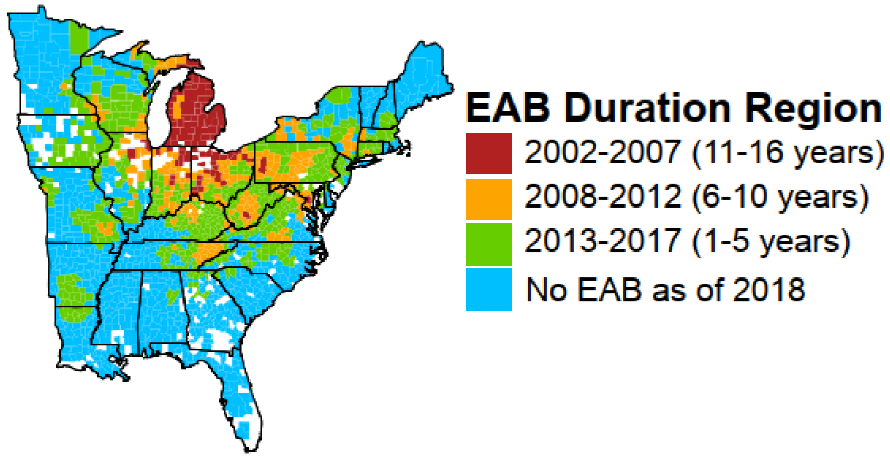


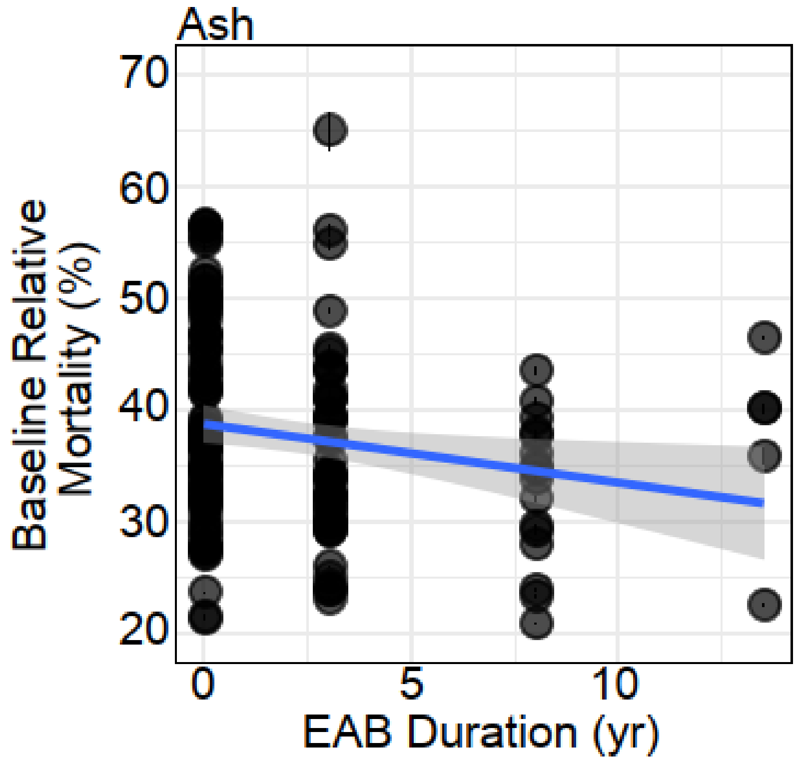
Eastern hemlock (co-variance in de Liocourt parameters)

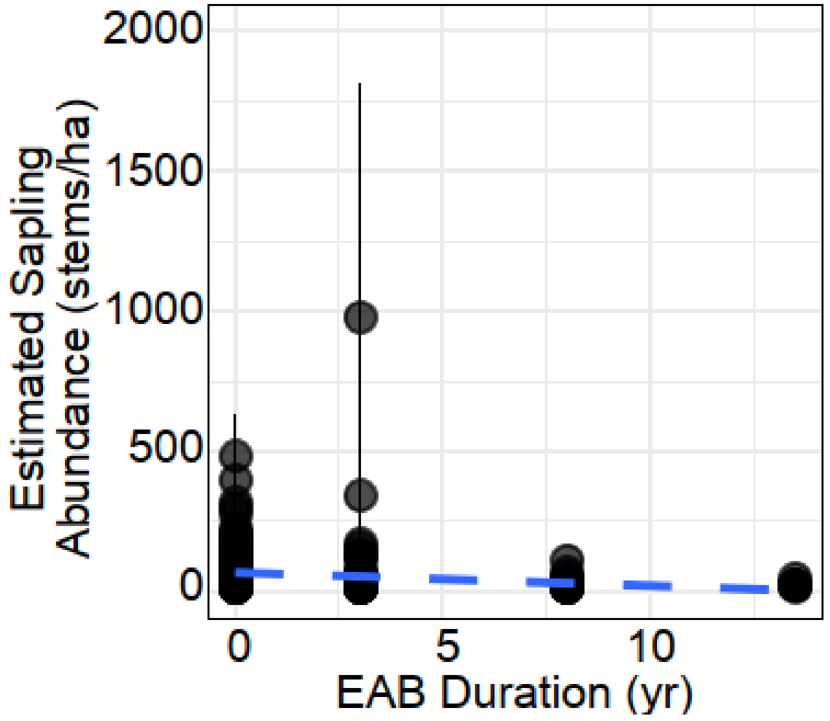


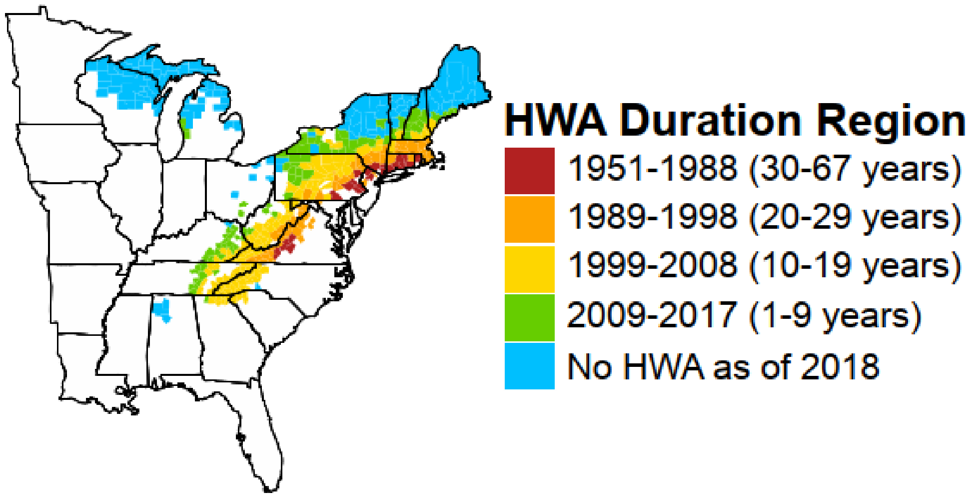



A
BBD Duration Region
1935-1950 (68-83 years)
1951-1960 (58-67 years)
1961-1980 (38-57 years)
1981-1990 (28-37 years)
1991-2005 (13-27 years)
2006-2017 (1-12 years)
No BBD as of 2018
B
American beech
Baseline Relative Mortality (%)
70
60
50
40
30
20
0
20
40
60
BBD Duration (yr)
C
Estimated Sapling Abundance (stems/ha)
600
400
200
0
0
20
40
60
BBD Duration (yr)

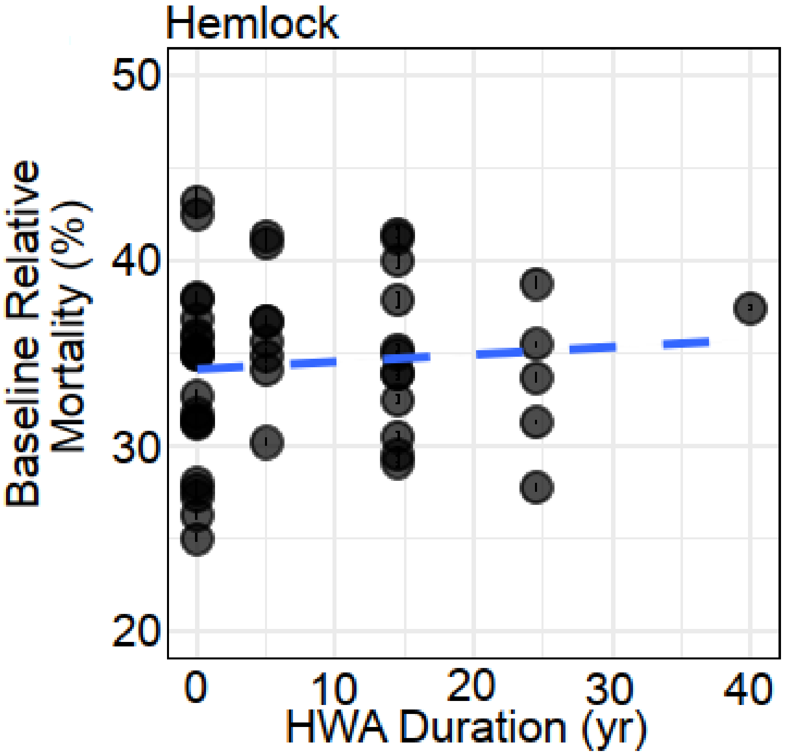

EAB Duration Region
2002-2007 (11-16 years)
2008-2012 (6-10 years)
2013-2017 (1-5 years)
No EAB as of 2018

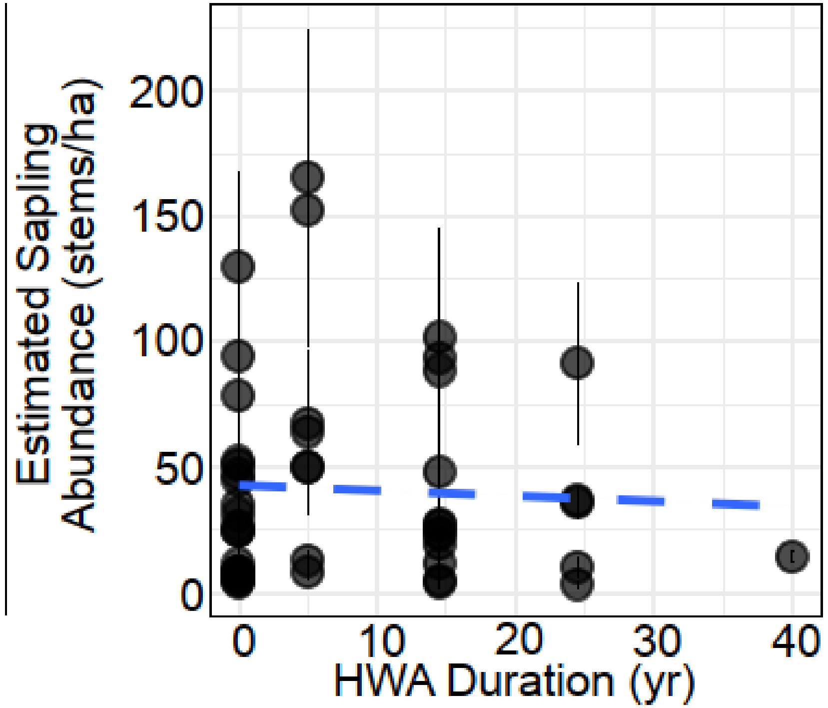

Ash
Baseline Relative Mortality (%)
70
60
50
40
30
20
0
5
10
EAB Duration (yr)

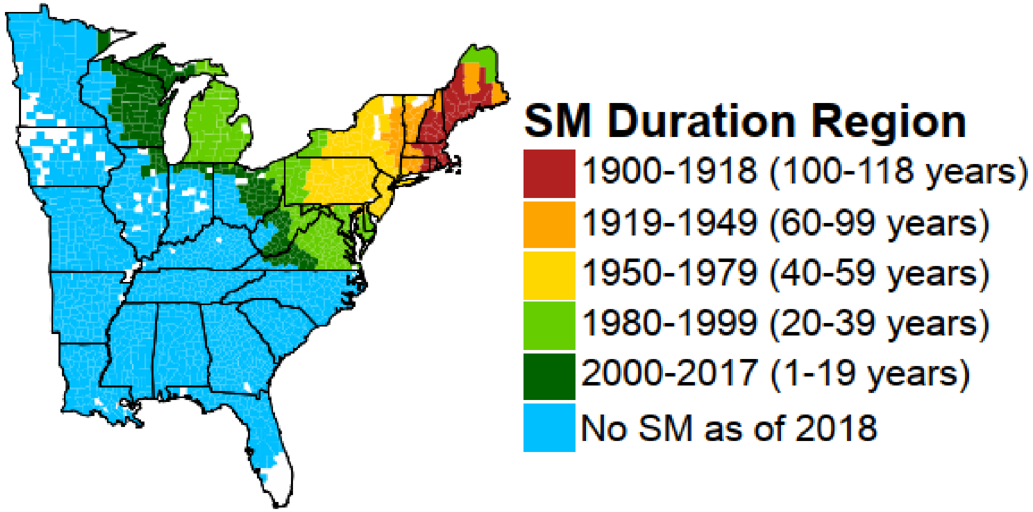

Estimated Sapling Abundance (stems/ha)
2000
1500
1000
500
0
0
5
10
EAB Duration (yr)

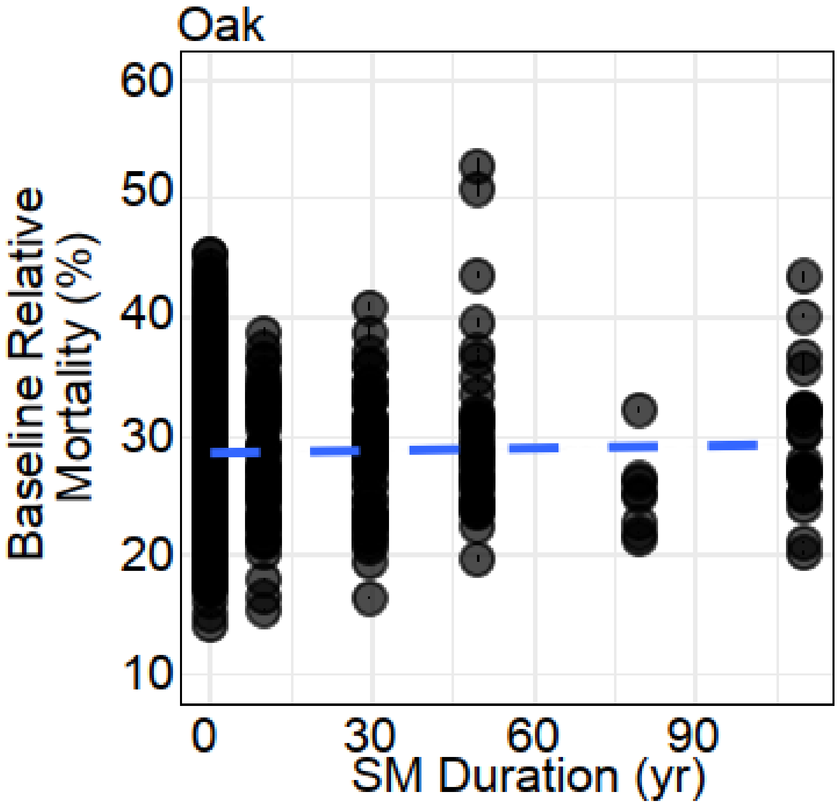

HWA Duration Region
1951-1988 (30-67 years)
1989-1998 (20-29 years)
1999-2008 (10-19 years)
2009-2017 (1-9 years)
No HWA as of 2018

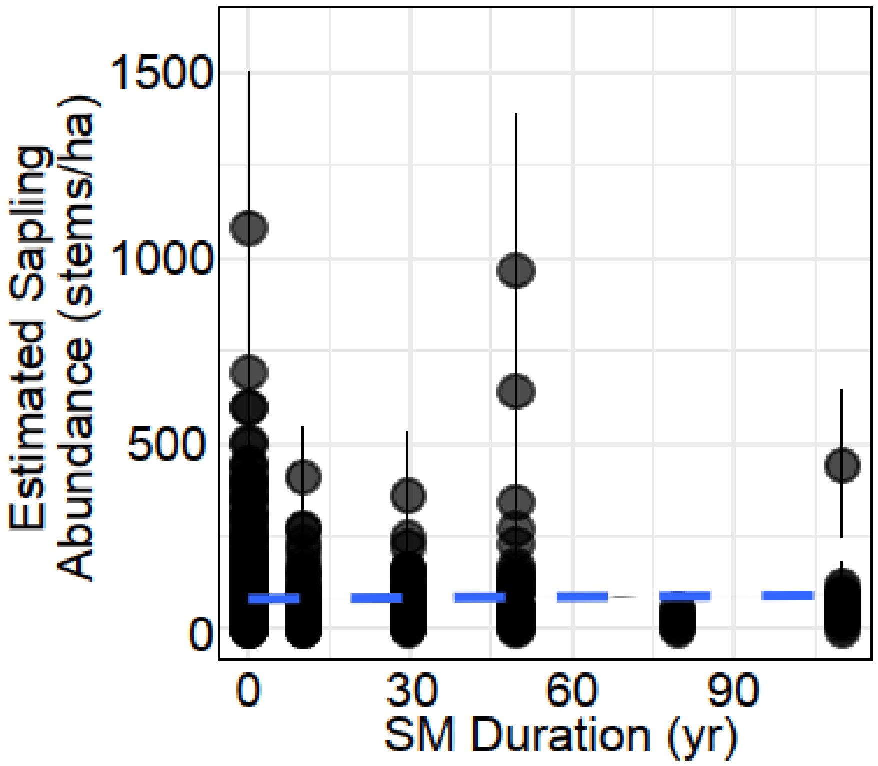

UGA3225077


Hemlock
Baseline Relative Mortality (%)
50
40
30
20
0
10
20
30
40
HWA Duration (yr)

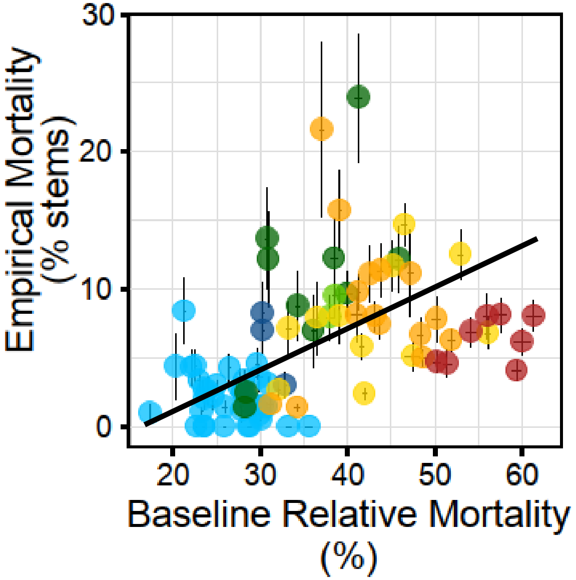

Estimated Sapling Abundance (stems/ha)
200
150
100
50
0
0
10
20
30
40
HWA Duration (yr)

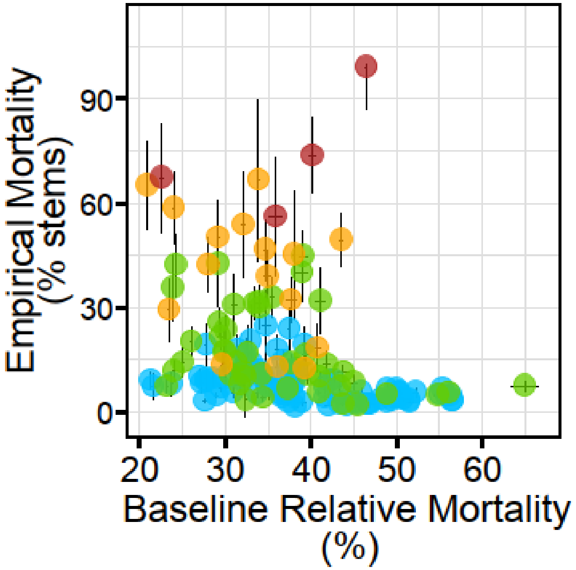

SM Duration Region
1900-1918 (100-118 years)
1919-1949 (60-99 years)
1950-1979 (40-59 years)
1980-1999 (20-39 years)
2000-2017 (1-19 years)
No SM as of 2018

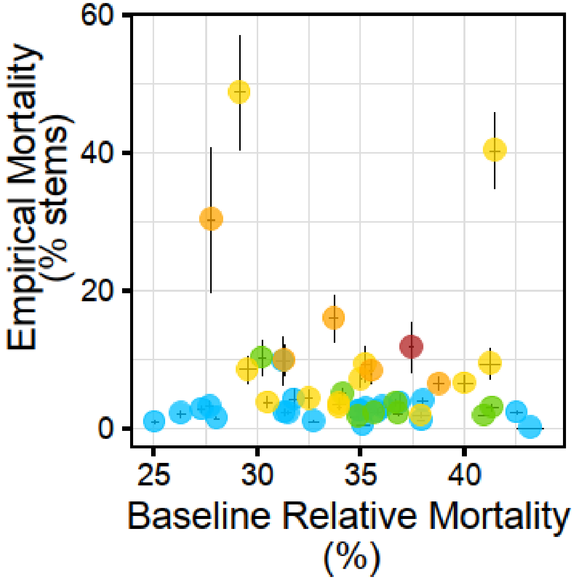

Oak
Baseline Relative Mortality (%)
10
20
30
40
50
60
0
30
60
90
SM Duration (yr)

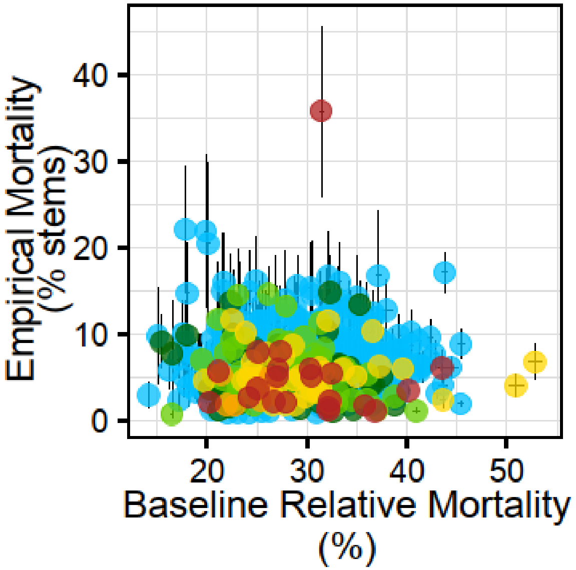

Estimated Sapling Abundance (stems/ha)
0
500
1000
1500
0
30
60
90
SM Duration (yr)

Empirical v. “equilibrium” mortality

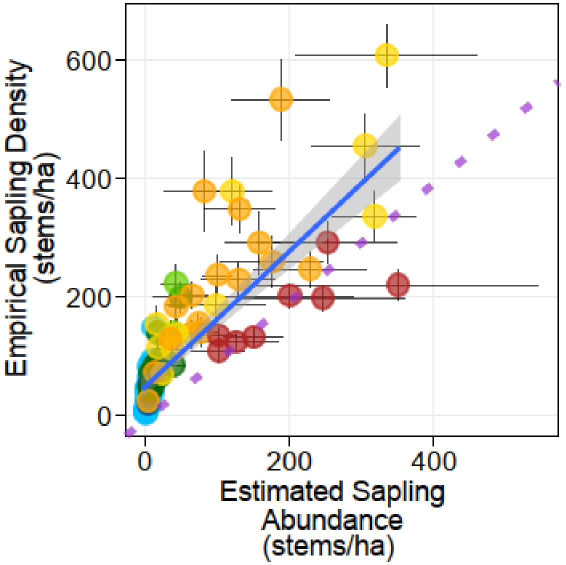


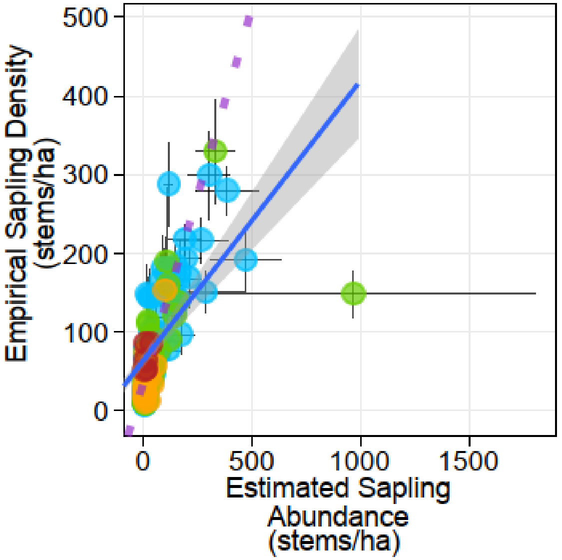


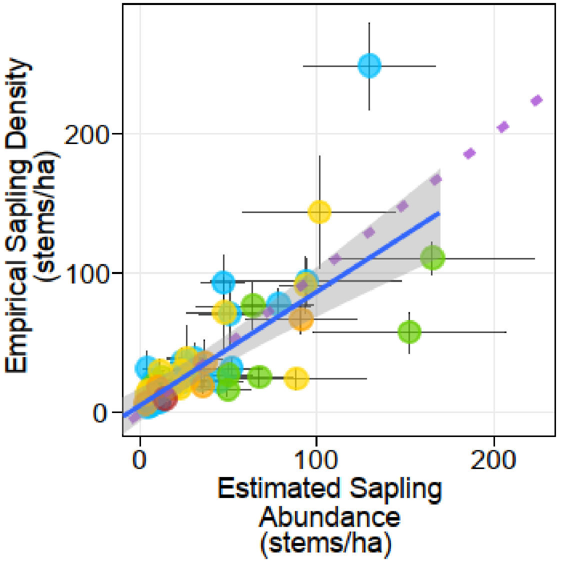


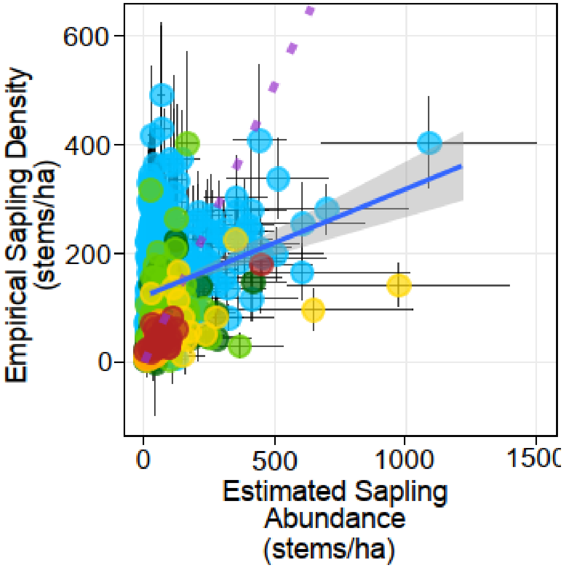


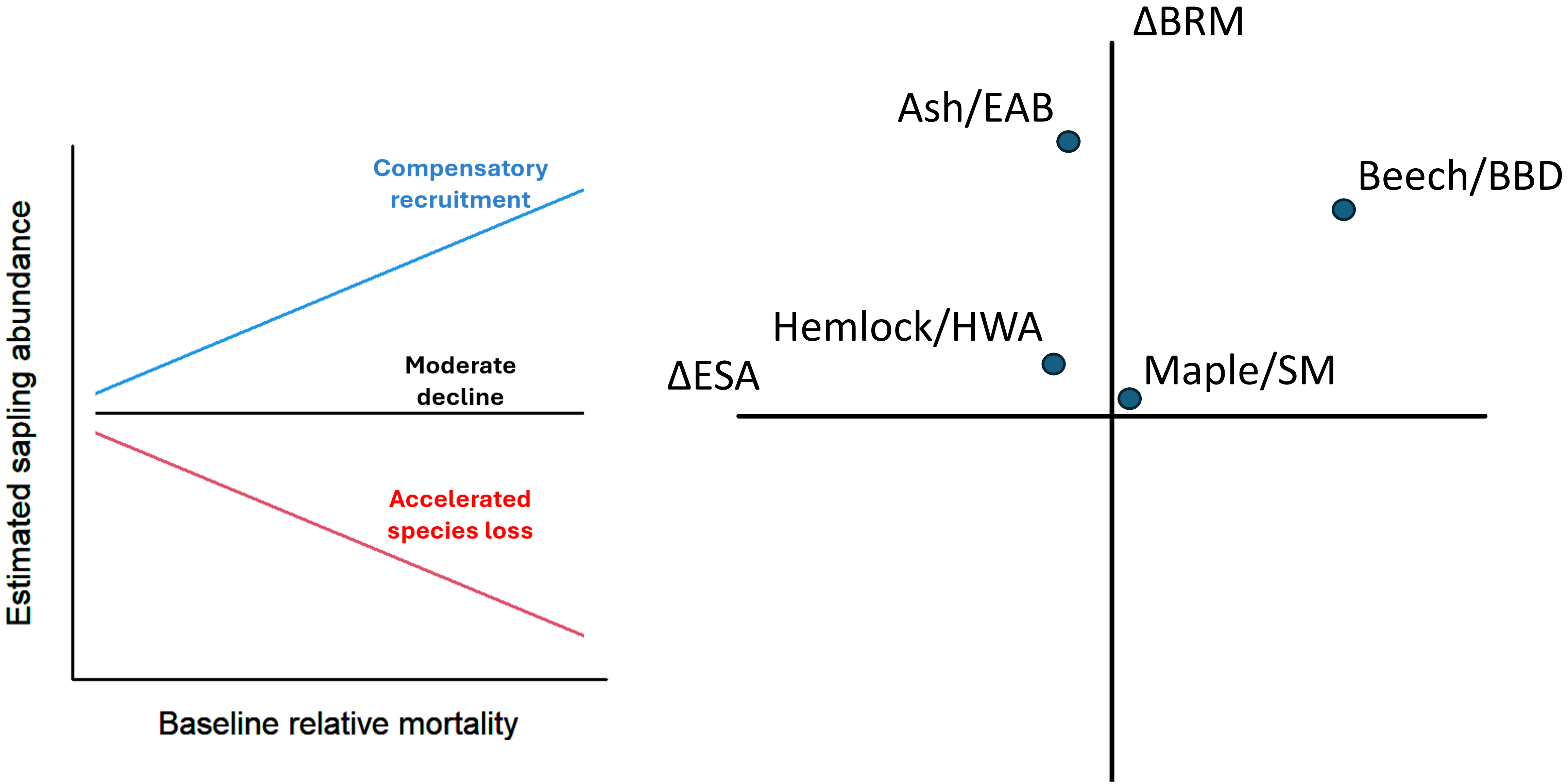
Empirical v. "equilibrium" sapling density










Compensatory recruitment
Moderate decline
Accelerated species loss
Estimated sapling abundance
Baseline relative mortality
ΔBRM
ΔESA
Ash/EAB
Beech/BBD
Hemlock/HWA
Maple/SM

Take aways (for now)

- Some proof of concept for the de Liocourt approach
  - Empirical estimates of sapling abundance (but not mortality) largely align with static forest structure snapshot
  - "Choice" of spatial and temporal scales matters A LOT!
- Range of outcomes vary but American beech *(and to a lesser degree American elm; not shown)* appear to be outliers in the strength of their compensatory response

Thanks for listening!