Climate change-associated declines in tree longevity are related to decreasing, not increasing, growth

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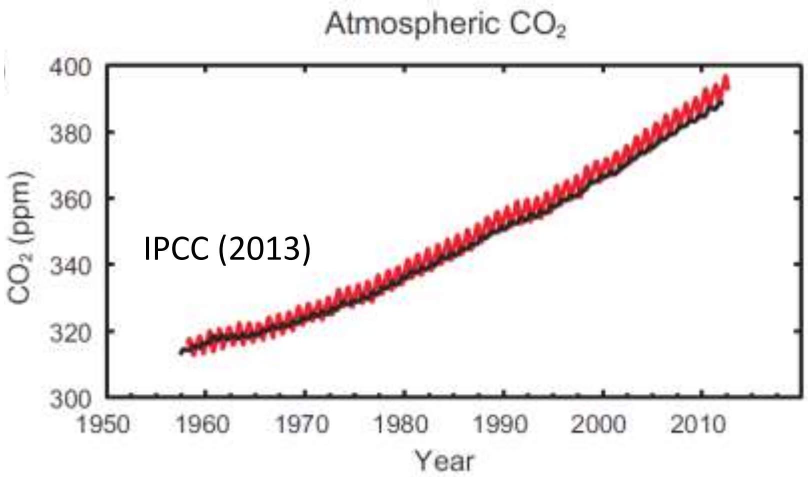
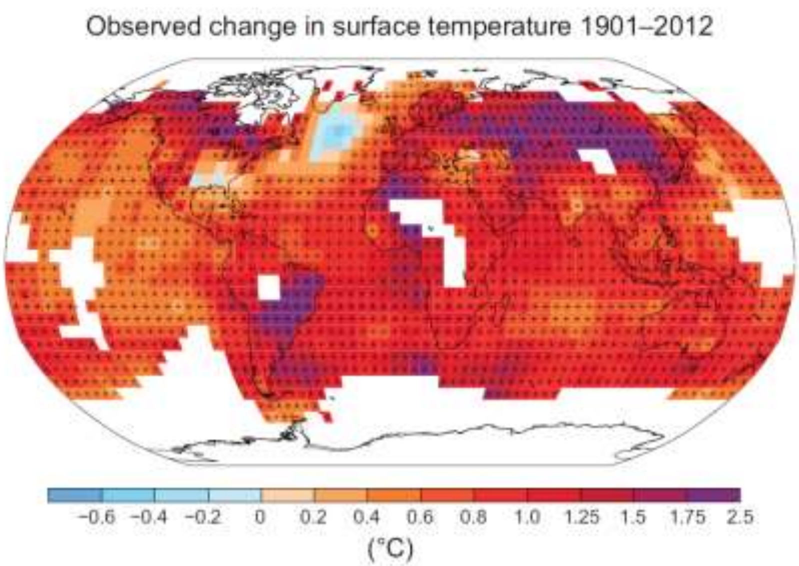
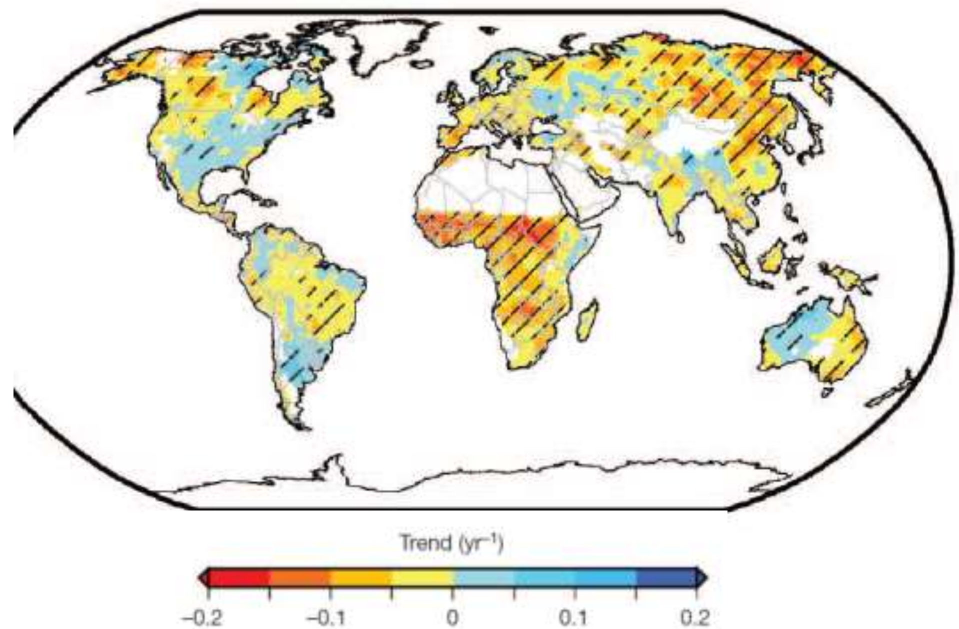


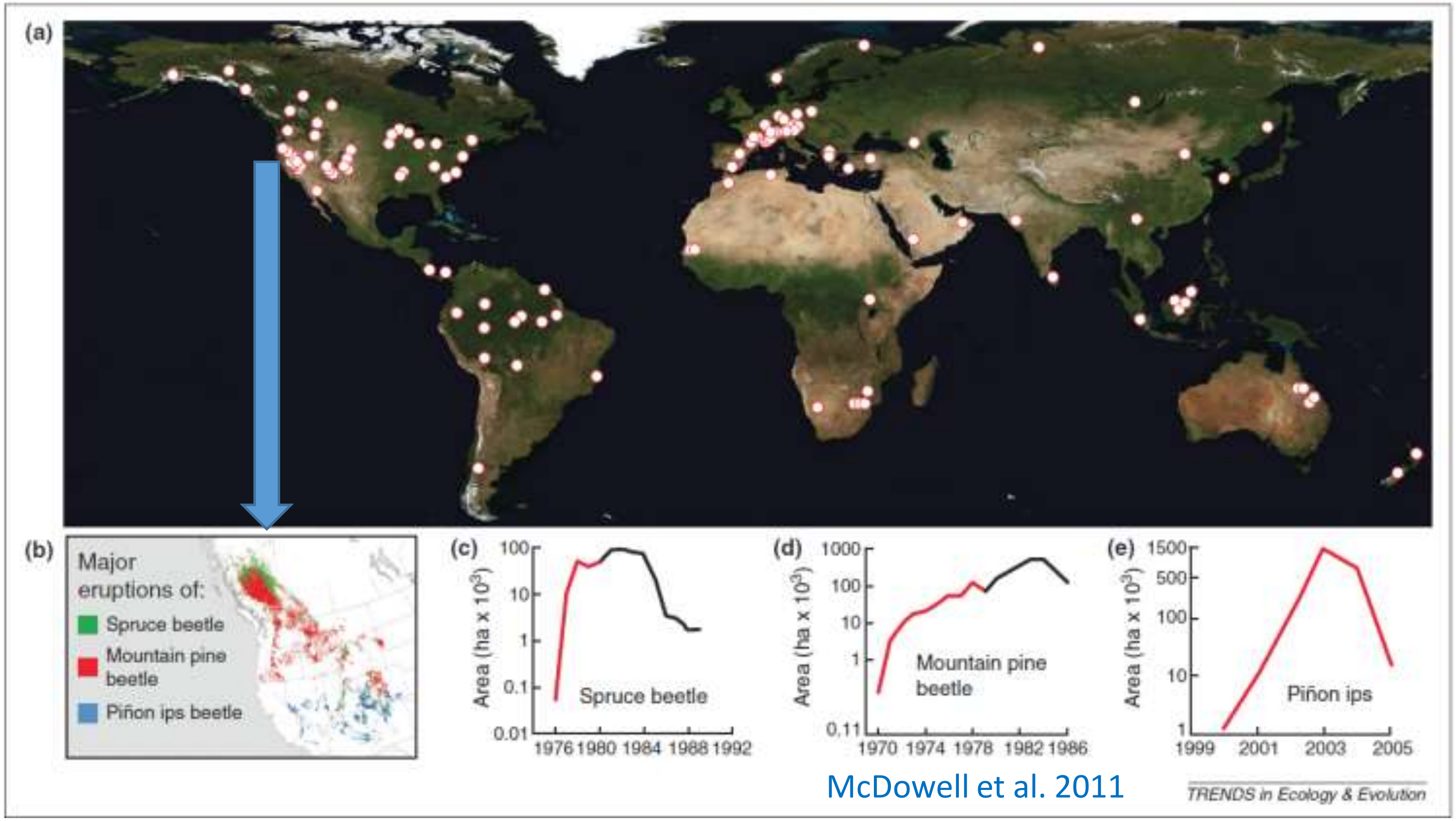


Water availability trends for past 60 years



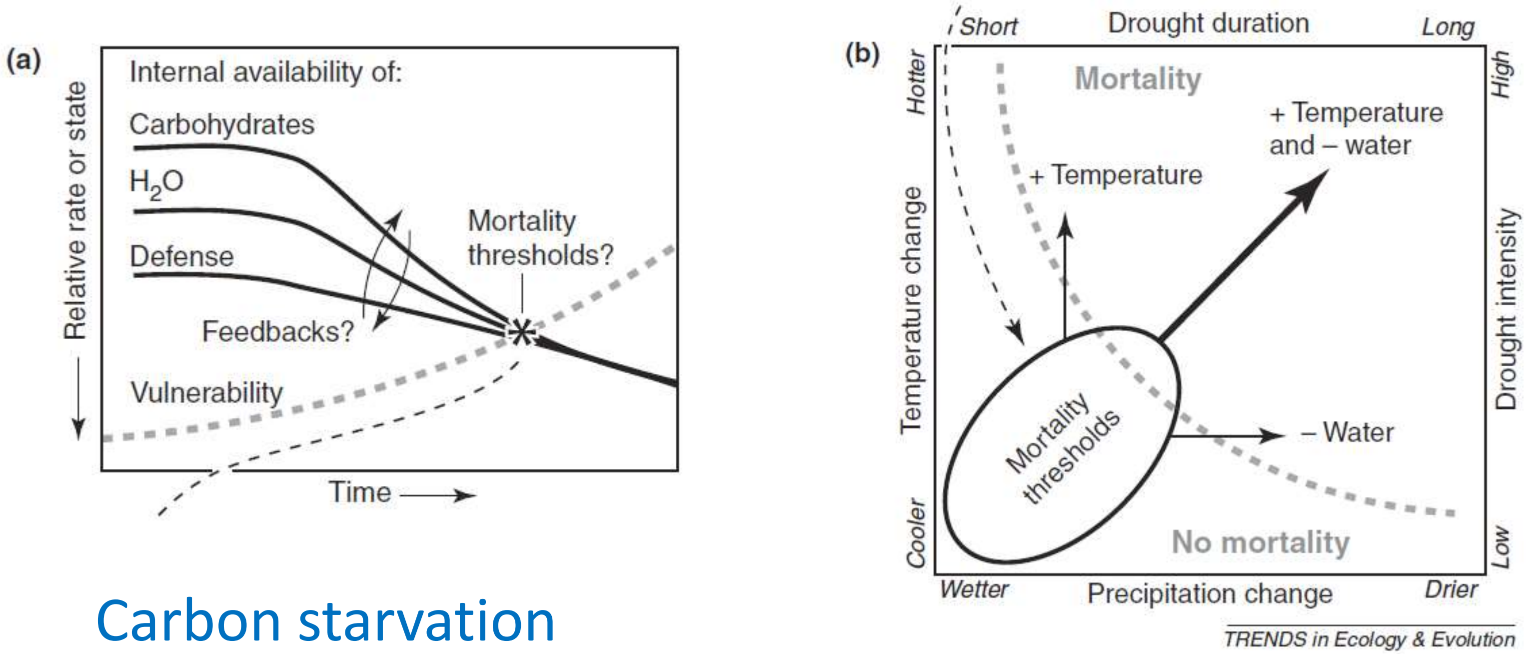
Sheffied et al. 2012. Nature **491**: 435

Global evidence of increased tree mortality

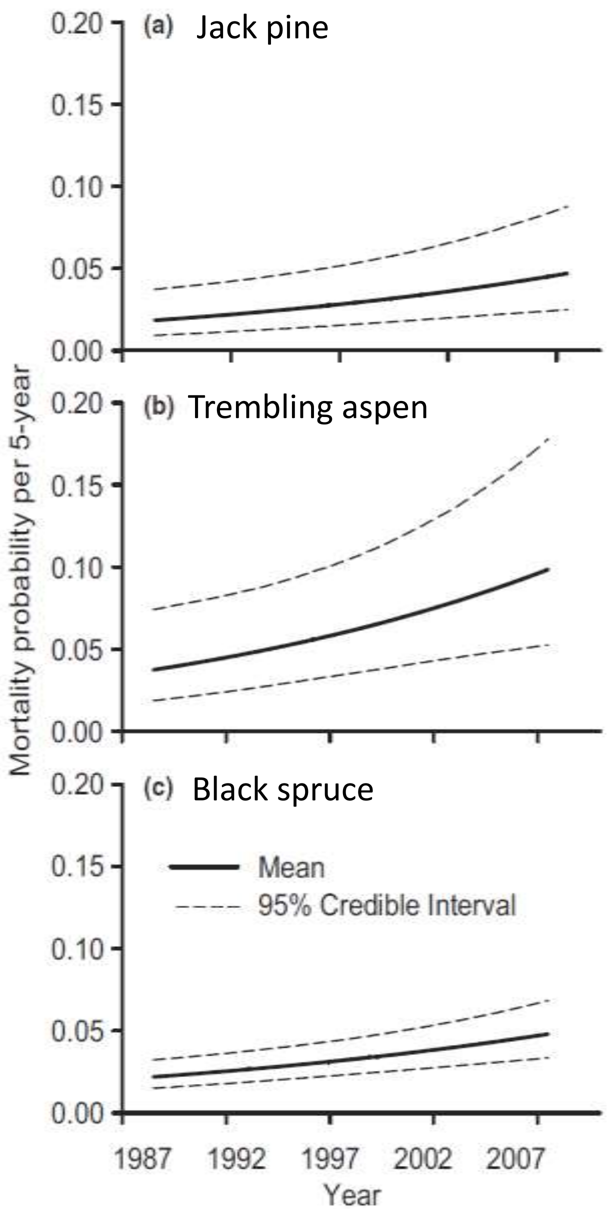


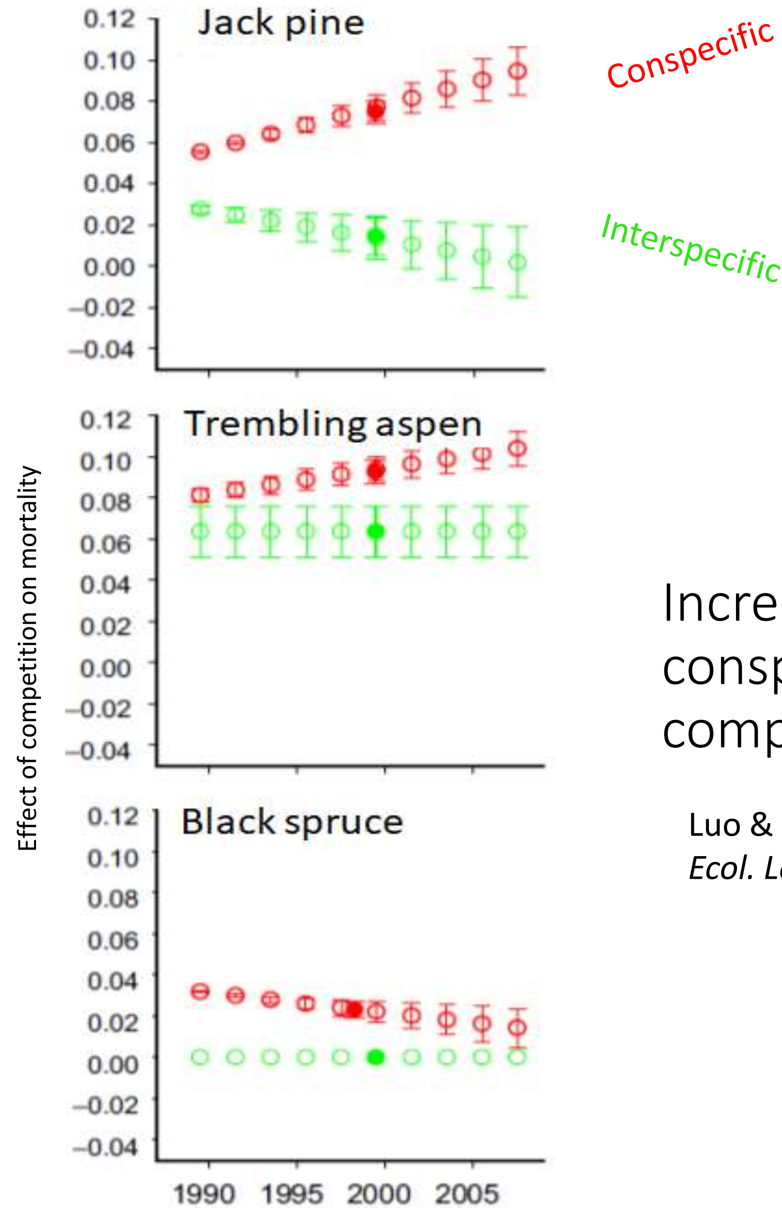
McDowell et al. 2011

Interdependent mechanisms



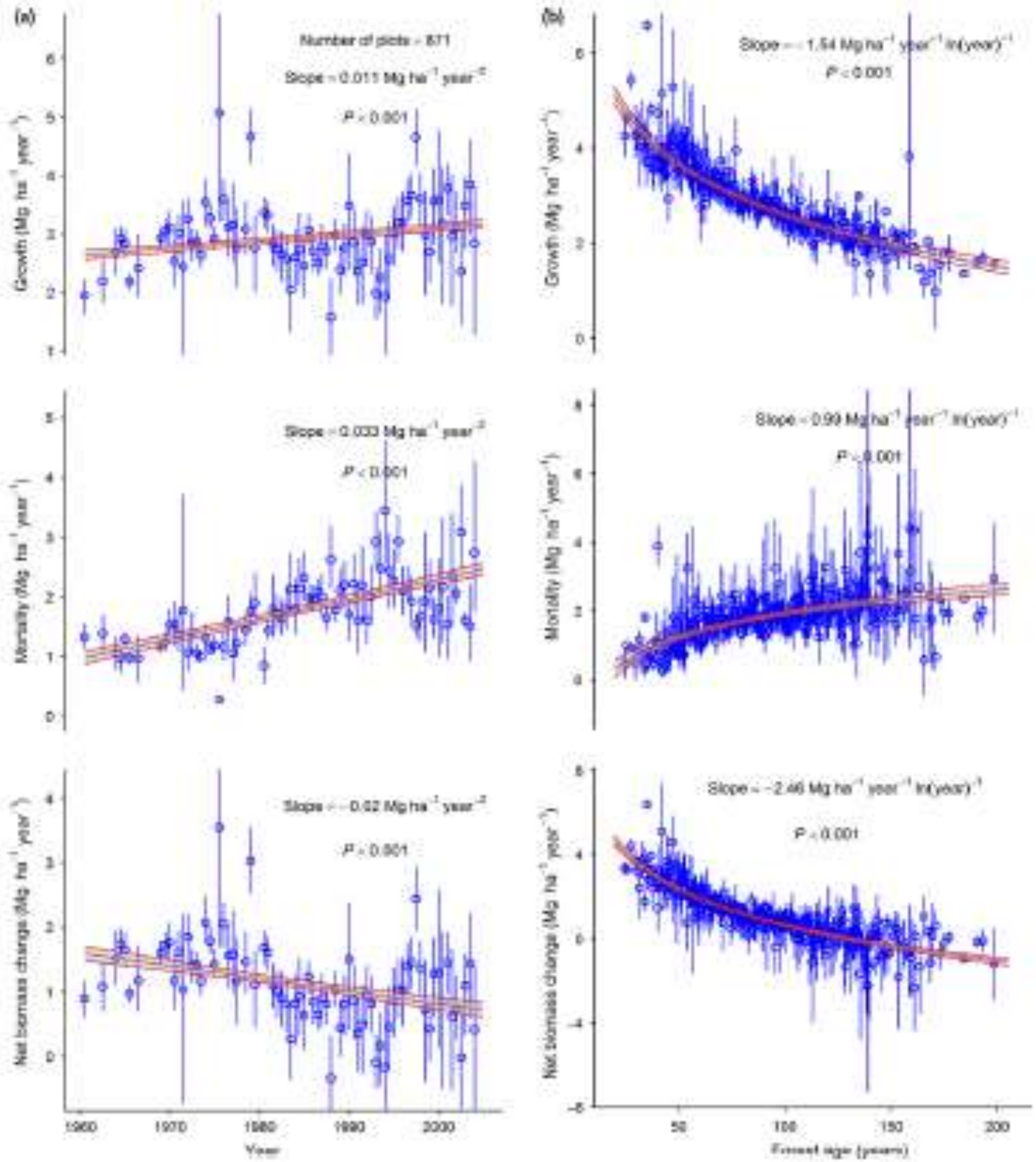
Carbon starvation
Hydraulic failure
Reduced defense to insects





Increased conspecific competition

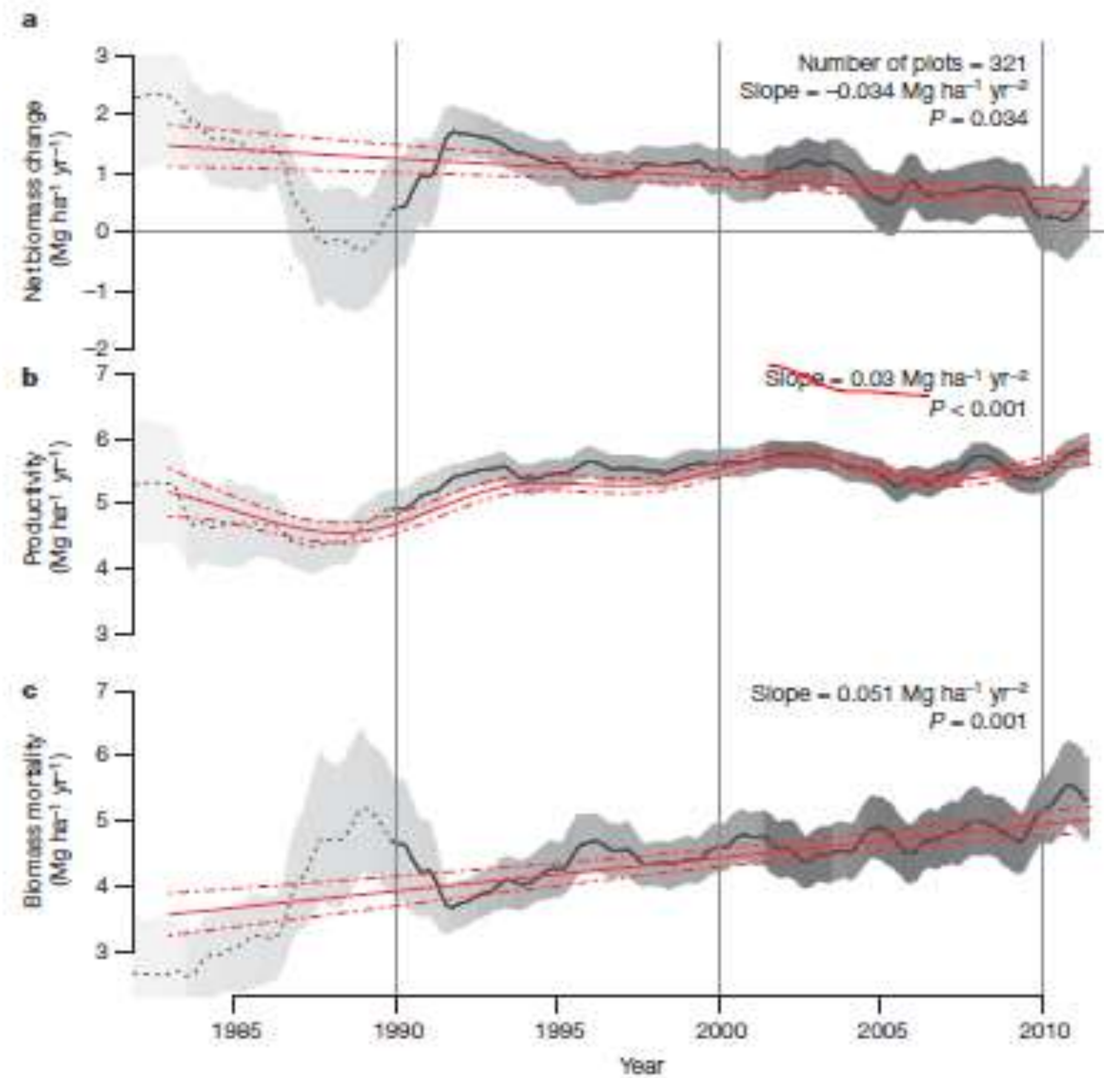
Luo & Chen 2015
Ecol. Lett.



Western boreal forests of Canada

Chen et al. 2016 *Ecol. Lett.*

Amazon tropical old-growth forest



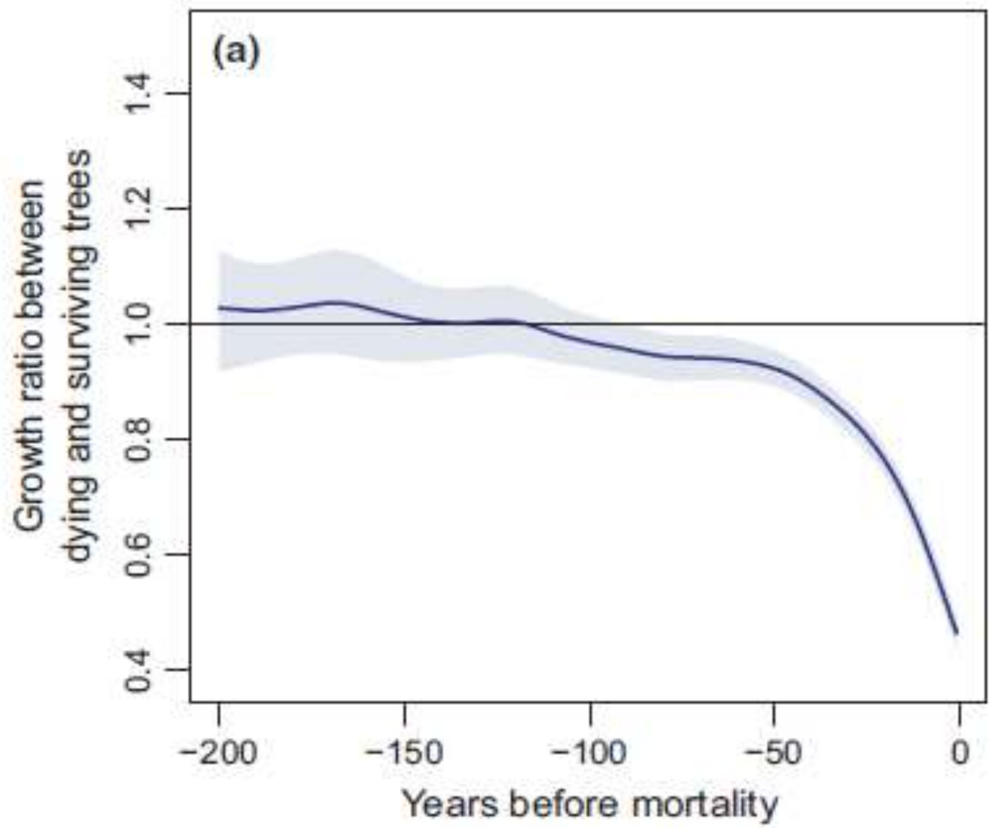
Reduced longevity by climate change-induced increased growth

Brien et al. 2015. *Nature*

Negative association between longevity and growth

- Among species
  - Greater investment in growth than defense, thus more vulnerable to stresses
- With species across spatial environmental gradients
  - Reaching large sizes sooner, more vulnerable to hydraulic failure and/or insect outbreaks

But temporally for same species



Radial growth patterns preceding tree mortality

Mortality driven by competition and/or longevity

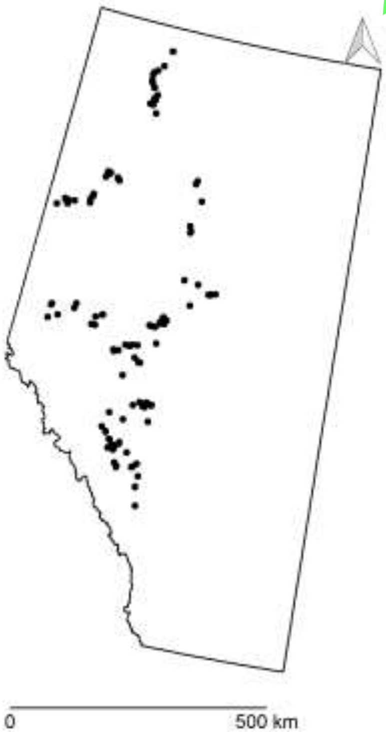
Cailleret et al. 2017, GCB.

Reduced tree longevity

- Tested by individual tree data
- Longevity driven mortality, not competition
- Detailed tree age

Our testable hypotheses

1. The probability of ageing driven tree mortality increases with climate change
2. Increases in mortality probability are associated with increasing growth prior to death



1958-2015

Plot and tree selection

1. Accurately determined stand age, time since fire (years)
2. Age of stands > 100 years old
3. Dominant trees, 200 largest trees per ha

Assumption

Age of dominant tree= stand age

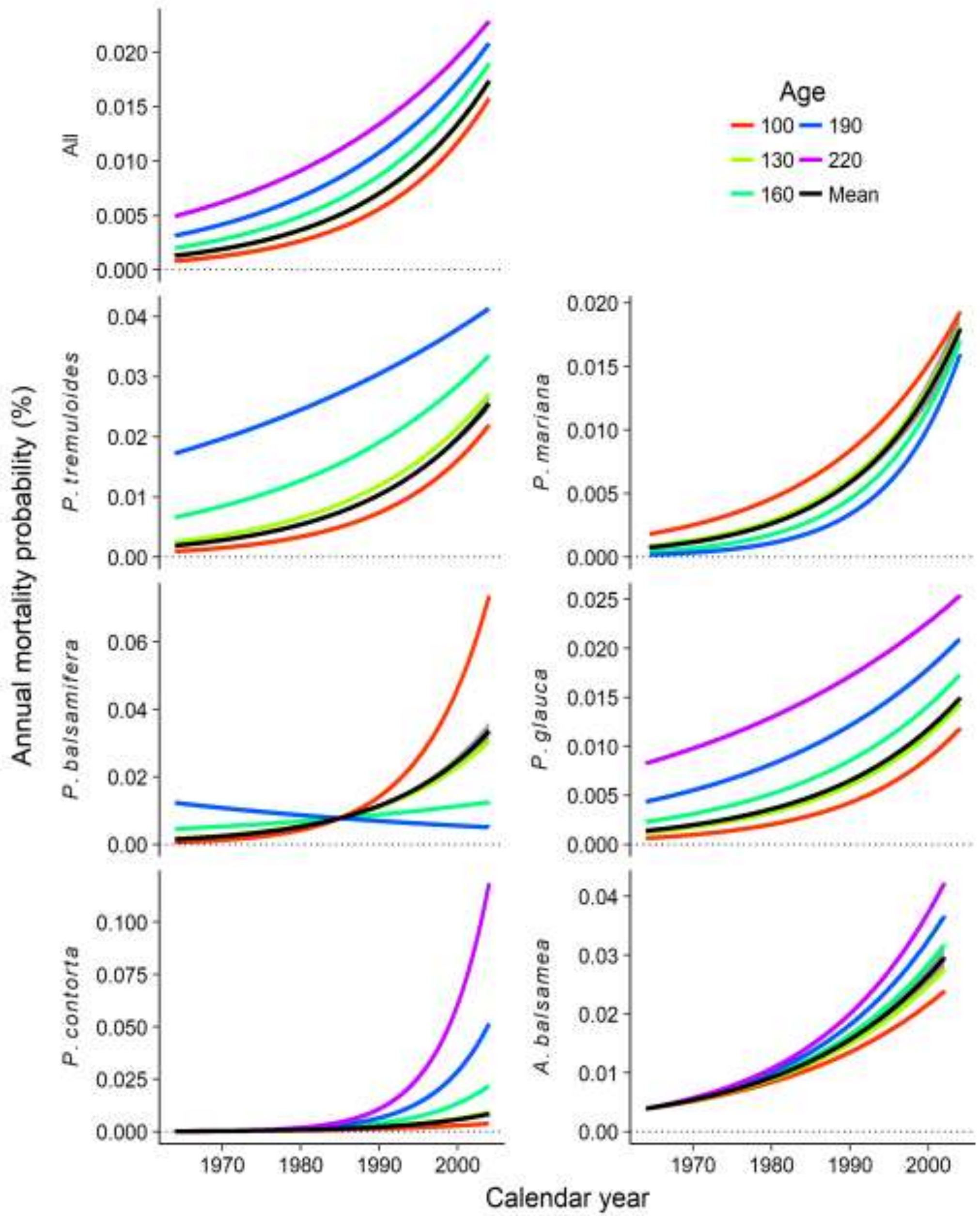
Species	Plots	Stems	Observations	Last age (years)
All individuals	**546**	**14418**	**44976**	**237**
P. tremuloides	287	3114	9467	196
P. balsamifera	136	717	2251	196
P. contorta	272	2866	8759	237
P. mariana	75	412	1228	184
P. glauca	442	6579	20849	216
A. balsamea	102	730	2422	216

Mortality model

$$\log\mathrm{it}(p_{ijk}) = \beta_0 + \beta_1 \cdot Y_{ijk} + \beta_2 \cdot A_{ijk} + \beta_3 \cdot Y_{ijk} \times A_{ijk} + \beta_4 \cdot \log(L)_{ijk} + \pi_k$$

Y, calendar year
A, tree age
L, census interval length
Π, plot random effect

Temporal increase in mortality



Relative growth rate model

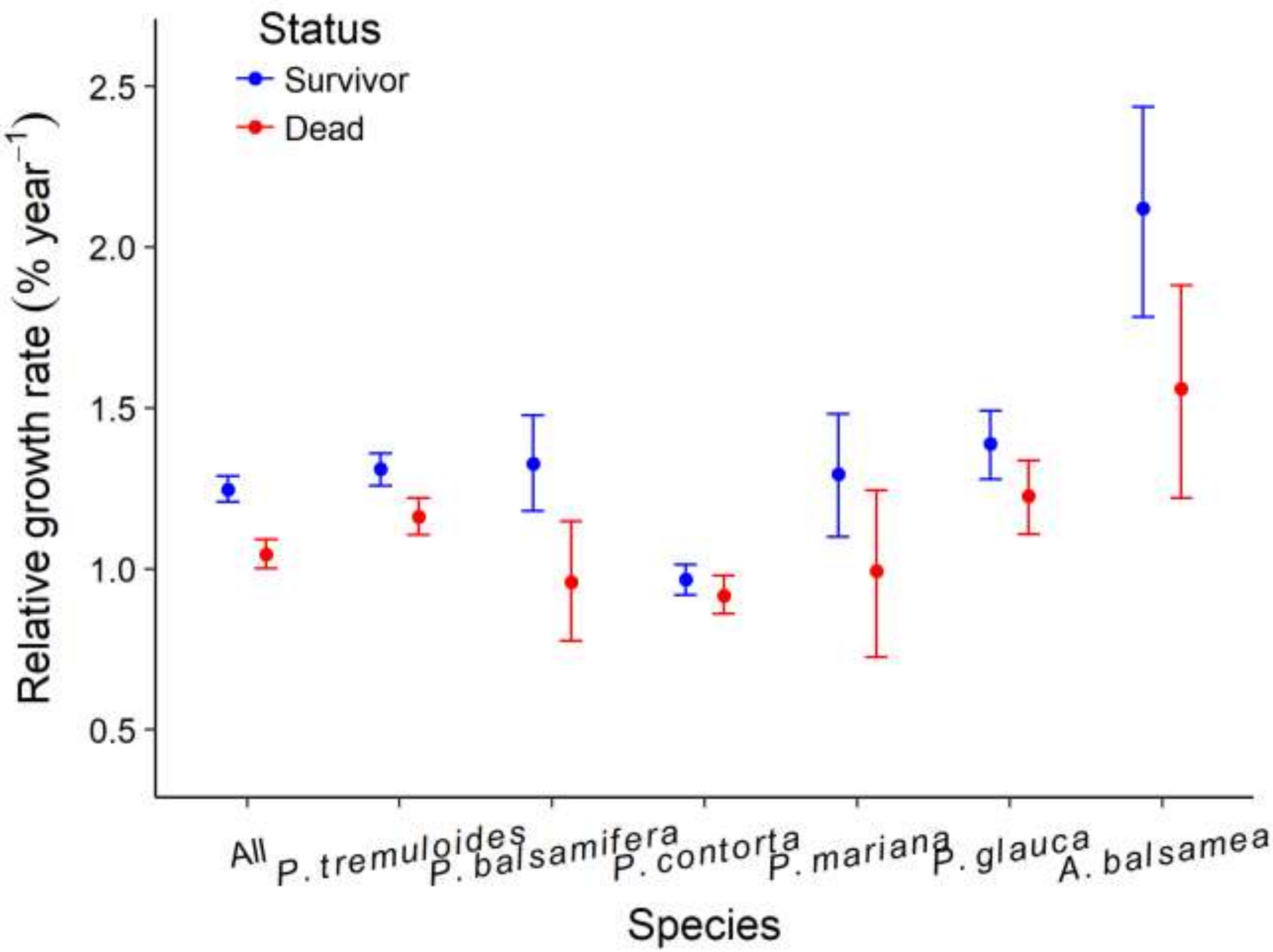
$$RGR_{ij-1k} = \beta_0 \cdot S_{ijk} + \beta_1 \cdot Y_{ij-1k} + \beta_2 \cdot A_{ij-1k} + \pi_k + \rho_{ik}$$

S, tree status

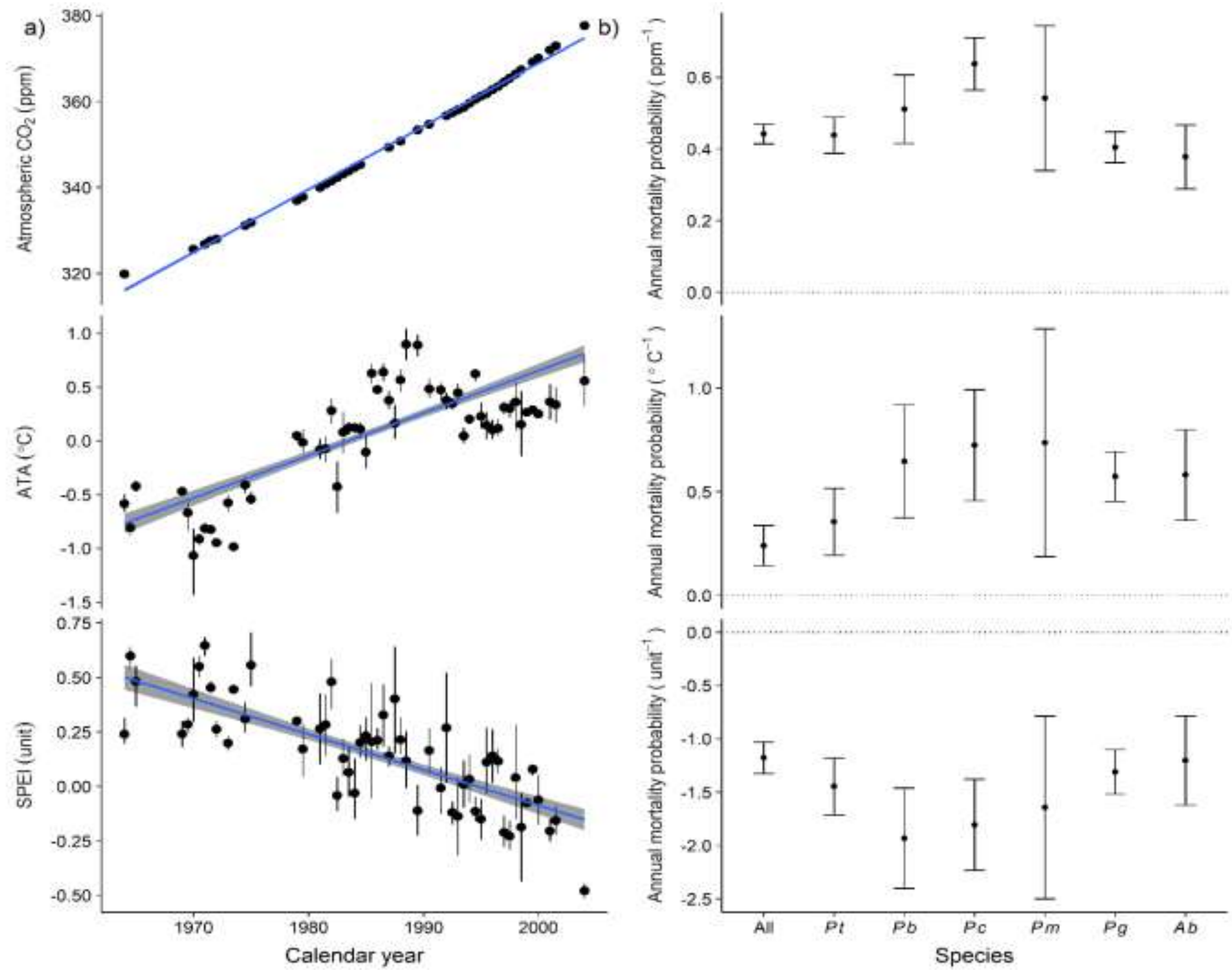
Y, calendar year

A, tree age

Relative growth rate



Mortality response to climate change drivers



Summary

- Climate change (CO_2, warming, and decreasing water availability) increased mortality of dominant trees in old stands, reducing tree longevity
- Increased tree growth is not a driver of reduced longevity. Instead, reduced longevity is likely caused by long-term climate change induced stress on growth