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

Eric B. Searle & Han Y. H. Chen
Lakehead University, Canada

Water availability trends for past 60 years

IPCC (2013)
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
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
<table>
<thead>
<tr>
<th>Species</th>
<th>Plots</th>
<th>Stems</th>
<th>Observations</th>
<th>Last age (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All individuals</td>
<td>546</td>
<td>14418</td>
<td>44976</td>
<td>237</td>
</tr>
<tr>
<td><em>P. tremuloides</em></td>
<td>287</td>
<td>3114</td>
<td>9467</td>
<td>196</td>
</tr>
<tr>
<td><em>P. balsamifera</em></td>
<td>136</td>
<td>717</td>
<td>2251</td>
<td>196</td>
</tr>
<tr>
<td><em>P. contorta</em></td>
<td>272</td>
<td>2866</td>
<td>8759</td>
<td>237</td>
</tr>
<tr>
<td><em>P. mariana</em></td>
<td>75</td>
<td>412</td>
<td>1228</td>
<td>184</td>
</tr>
<tr>
<td><em>P. glauca</em></td>
<td>442</td>
<td>6579</td>
<td>20849</td>
<td>216</td>
</tr>
<tr>
<td><em>A. balsamea</em></td>
<td>102</td>
<td>730</td>
<td>2422</td>
<td>216</td>
</tr>
</tbody>
</table>
Mortality model

\[
\text{logit}(p_{ijk}) = \beta_0 + \beta_1 \cdot Y_{ijk} + \beta_2 \cdot A_{ijk} \\
+ \beta_3 \cdot Y_{ijk} \times A_{ijk} + \beta_4 \cdot \log(L)_{ijk} + \pi_k
\]

Y, calendar year
A, tree age
L, census interval length
\( \Pi \), 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

![Graph showing relative growth rate for different species and status (Survivor vs. Dead).](image)
Mortality response to climate change drivers
Summary

• Climate change (CO2, 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