The effects of multiple stresses on Fraser fir physiology in Great Smoky Mountains National Park

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Southern “Boreal” Forests

- Occur in eastern TN, western NC and southern VA
- “Island-like” relict population from 18,000-12,500 years ago (Delcourt and Delcourt 1987)
- Habitat to several rare and endemic species
- GRSM contains 74% of ~90,000 acres of remaining spruce-fir forests (Dull et al. 1988)

Abies fraseri

- Endemic to southern Appalachians (1767- 2037 m)
- Inbreeding and loss of heterozygosity
  (Potter et al. 2008)
- 30-80 ft. tall, 12” (30.5 cm) DBH at maturity
- 40 years to maturity
- Lifespan: 180-200 years
**Individual Stresses**

- **Balsam Wooly Adelgid**
  - Causes reduction in water and sap conductance and death in 2-5 years (Hollingsworth et al. 1991)

- **Moisture**
  - Moderate water stress reduced root and shoot biomass by 20%, as well as leaf conductance and transpiration (Tseng et al. 1988)

**Temperature**
- A 3°C increase in mean July temp -> raise niche 480 m in elevation (Delcourt and Delcourt 1998)
- Changes in phenology may increase frost damage, insect depredation (Emerson et al. 2006) or increase growth and fecundity (Rossi et al. 2011)
- *Picea rubens* seedlings from different seed sources responded differently to elevated warming (Hagen 2006)
Atmospheric Deposition

- wet, dry and fog deposition ~ 30 kg N ha\(^{-1}\) yr\(^{-1}\) (Johnson et al. 1991)
- ~20 kg N ha\(^{-1}\) yr\(^{-1}\) leach out (Nodvin et al. 1995)
- Increased soil acidity -> Al solubility -> decreases in Ca, K, and Mg
- Robarge et al. (1989) found elevated foliar Al

Atmospheric Deposition

- Decreases in Ca lead to increases in dark respiration (MacLaughlin et al. 1991)
- High S dep causes needle necrosis, early senescence and defoliation (Jacobson et al. 1990).
- Reduction in leaf chlorophyll content
- Lack of winter hardening (Adams and Eager 1992)

Multiple Stresses

What is the relative importance of these factors on growth?

Aber et al. 2001
Conservation

- Spruce-fir community rich in rare and endemic species
- Several species at risk of extinction
  - Northern Goshawk
  - Carolina Flying Squirrel
  - Spruce Fir Moss Spider
  - 5 more invertebrates
  - 12 plants
- Two endemic salamanders
  - Pygmy salamander
  - Imitator salamander

Southern Appalachian Man and the Biosphere 1996

Christmas!

- NC xmas tree industry generates ~$100 million annually
- Most of this is from plantation grown Fraser fir
- Maintenance of genetic diversity in wild pop.
- Identification of stress tolerant individuals -> heartier plantation stock

Potter et al. 2005
Research Objectives

- Determine relative importance of effects of temperature, water availability, soil pH, sulfur and nitrogen deposition and soil Ca:Al ratios on Fraser fir health.
- Develop a mechanistic model for determining moisture availability for trees at a given site.
- Identify stress tolerant Fraser fir individuals, and determine if there is an underlying pattern in health due to age or geographic location.
- Test whether hypothesized change in forest species/composition is occurring, and if so, if it's correlated with N deposition, BWA disturbance intensity or climactic parameters (temperature and moisture).
Long-term Monitoring

- Established in 1990
- 20m x 20m plots
- Not previously logged or burned

<table>
<thead>
<tr>
<th>≥ 65% of over-story Fraser fir living</th>
<th>≥ 65% of over-story Fraser fir dead</th>
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<tr>
<td>Pure Live Fir</td>
<td>Pure Dead Fir</td>
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<tr>
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- 37 plots total

Long-term Monitoring

- All live and dead over-story trees (>5 cm) were counted by species, tagged, and DBH
- 5 co-dominant firs per plot cored and aged in 2000
- BWA and crown dieback noted
- growth rates
- mortality and recruitment rates
- species richness
- understory was also sampled

How do we measure tree health?

Photosynthesis
(Shoot health)

Transpiration
(Root health)

Growth

Nutrients

Soil moisture
Photosynthesis and Transpiration

- Measure with Intra-red Gas Analyzer (IRGA)
- \( A_{\text{net}} \) does not decline until after 6 min (Meng and Arp 1993)

Leaf Pigments

- Leaf Chlorophyll A and B content
- Leaf Carotenoid Content
- extract pigments with acetone
- measure light absorbance in a spectrophotometer at 480, 663, and 645
- formulas developed by Sestak et al. (1971) and Davies (1976)

Non Structural Carbohydrates

- Stem tissue obtained with Increment Borer
- Root Samples also collected
- Methods developed by Chow and Landhäusser (2004)
Environmental Variables

- N and S deposition (Weathers and Lindburg Model 2006)
- Temperature
- Mechanistic Model of Soil Moisture Availability
  - Precipitation
  - Infiltration rates
  - Soil depth
  - Soil saturation levels

Cai et al. (2011) show significant differences between A and B horizons
- 8 soil cores per plot < 25 cm depth
- Soil parameters
  - pH (1:1 soil:water method)
  - Ca:Al (ICP-MS)
  - Macro- and Micronutrients (ICP-MS)

Statistical Methods

- Multivariate Regression
  - Pigments, $A_{max}$, TE, TNC = Temp, H$_2$O availability, soil pH, Ca:Al ratios, Nutrients, N and S dep
  - McHenry’s Algorithm for variable selection
  - Jack-knife to test for model predictability
- PCA: health
  - Age, Geographic Location
  - Identify robust individuals
- DA: Changes in Hardwood Percentages
  - N dep, climactic variables, historical BWA disturbance intensity
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References


