Bonanza Creek Experimental Forest: Historical perspectives and future outlooks on research

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C0-PI BNZ LTER
Introduction to Bonanza Creek Experimental Forest (BCEF)

- Only designated forest research facilities in the true boreal forest zone of the United States
- It lies within the Tanana Valley State Forest
- On Alaska state land, with Forest Service and university research conducted under a long-term lease and cooperative agreement.
- Located about 20 km southwest of Fairbanks
BCEF Timeline

- Institute of Northern Forestry (INF) was dedicated on **July 1st, 1963** and coincided with the establishment of BCEF to encompass ~3,360 ha of upland interior Alaska boreal forest.
- In **1969**, the forest was enlarged to include an additional ~5,053 ha of representative floodplains along the Tanana River.
- The Rosie CK Fire consumes 1/3 of BCEF in **1983**
- Bonanza Creek was became a designated Long Term Ecological Research (LTER) site in **1987**
- In **1995**, PNW Research Station closed in INF.
- In **1999**, in an effort to preserve a Forest Service presence in boreal Alaska, BECRU was established
- On **6/30/2018**, 55 years will have passed since the BCEF was established and will require a lease renewal with the State of Alaska.
On the shoulders of our forefathers

Initial Research (1950s-1980s)

- Fire disturbance (V. Johnson, USFS)
- Vegetation Composition and ecosystem processes (L. Viereck, USFS)
- Forest management, silviculture, tree regeneration (J. Zasada, USFS)
- Nutrient cycling & stand productivity (K. Van Cleve, UAF)
- Insect populations (R. Beckwith and R. Werner, USFS)
- Moose/vegetation interactions (J. Byrant, UAF)
- Tree Genetics (J. Alden, USFS)
- Soil formation and “Turning Points (T. Dryness, USFS)
Leslie A. Viereck

Research interests and BCEF projects
- Role of fire and flooding on vegetation composition
- The interaction and linkages between fire, permafrost, and vegetation
- Forest classification and flora

Claims to Fame
- Establishment of BCEF
- Alaska Trees and Shrubs
- Alaska Vegetation Classification
John Zasada

Research interests and BCEF projects
- Effects of scarification coupled with harvest technique on white spruce regeneration

Claims to Fame
- Zazada Road in BCEF
- White Spruce needs mineral soil to effectively germinate
Keith Van Cleve

Research interests and BCEF projects
- Differences in nutrient cycling and stand productivity through floodplain succession

Claims to Fame
- State Factor concept which provided a powerful basis for understanding factors affecting current forest production and the underlying processes associated.
- Used the idea of “turning points” to look at the transitions between successional stages.

Figure 1. State factors and ecosystem controls of element cycling in interior Alaskan forests.
John Bryant

Research interests and BCEF projects
- Effects of herbivory on vegetation composition
- The role of secondary compounds in protecting plants from herbivory

Claims to Fame
- Establishment of the moose exclosures that are still being monitored and expanded today.
John Alden

**Research interests and BCEF projects**
- Variation within and among commercial tree species
- Introduction, adaptability, and growth of foreign commercial tree species

**Claims to Fame**
- Lodgepole pine plantation
- Seed source for various providences
BNZ LTER - Award History


2004-2006: LTER 4a: *The Dynamics of Change in Alaska’s Boreal Forests: Resilience and Vulnerability in Response to Climate Warming* (PI: Chapin)

2006-2010: LTER 4b: *The Dynamics of Change in Alaska’s Boreal Forests: Resilience and Vulnerability in Response to Climate Warming* (PI: Chapin)


2017-2023: LTER6: *Cross-Scale Controls Over Responses of the Alaskan Boreal Forest to Changing Disturbance Regimes* (PI: Ruess)
Evolution of Bonanza Creek LTER Research

- **1987-1992**: Successional dynamics
  - Comparisons along chronosequence
  - Initiate long-term experiments
- **1993-1998**: Landscape processes
  - Add experimental watersheds
- **1999-2010**: Regional climate-disturbance interactions
  - Expanded temporal and spatial scales
  - Disturbance-climate-ecosystem interaction
H1 = Successional = life history traits modified by facilitative and competitive interactions

H2 = Vegetation-caused changes in resource (light, nutrients, moisture) availability during succession controls ecosystem function

H3 = Successional declines in labile C affects SOM mineralization, nutrient availability and plant growth

H4 = Herbivores promotes replacement of palatable species by unpalatable species.

FLOODPLAIN PRIMARY SUCCESSION

<table>
<thead>
<tr>
<th>STAGES</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
<th>VIII</th>
<th>IX</th>
<th>X</th>
<th>XI</th>
<th>XII</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGE (Years)</td>
<td>0-1</td>
<td>1-2</td>
<td>2-5</td>
<td>5-10</td>
<td>20-40</td>
<td>80-100</td>
<td>125-175</td>
<td>200-300</td>
<td>300-500</td>
<td>500-1000+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FA0</td>
<td>Bare surface, initial stage</td>
<td>Bare surface, salt crust</td>
<td>Open shrub</td>
<td>Closed Shrub</td>
<td>Young balsam poplar</td>
<td>Alder</td>
<td>Young white spruce, mature balsam poplar</td>
<td>Old balsam poplar, white spruce</td>
<td>Mature white spruce</td>
<td>Old white spruce</td>
<td>Mixed white and black spruce</td>
<td>Black spruce and thaw ponds</td>
</tr>
</tbody>
</table>

SUCCESSEIONAL TRAJECTORY
How is the boreal biome responding to climate change and what are the local, regional, and global impacts of those responses?
How do climate and disturbance regime alter the functioning of the boreal forest?
LTER 3 Research Themes

- Forest Dynamics
- Carbon Dynamics
- Disturbance Dynamics

Relations:
- Forest Dynamics affects Carbon Dynamics and Disturbance Dynamics.
- Carbon Dynamics affects Disturbance Dynamics.
- Disturbance Dynamics affects Forest Dynamics.
Task 1. Document climate: The microclimate to which community and ecosystem processes respond is determined more strongly by disturbance and vegetation than by macroclimate.

Monitor macro & microclimate/permafrost
LTER 3a (1998-2000): Interaction of Multiple Disturbances with Climate in the Alaskan Boreal Forest

Task 2. Document the disturbance regime: Historic and contemporary feedbacks among major boreal disturbances (fire size and probability, logging, insects, and flooding) result in a highly interactive disturbance regime that responds nonlinearily to changes in climate and land use.

Task 3. Document impacts of climate and disturbance regime on population dynamics and diversity: Type and severity of disturbance influence population dynamics, community composition, and diversity more strongly than does climate.


Disturbance type & severity + seed avail = successional trajectory

B-diversity strongly affected by landscape structure – affecting speed, trajectory and endpoints of succession
Alaska’s Changing Fire Regime

High severity fires burning through organic horizons to mineral soil favor the establishment of hardwoods over conifers.

Predictions are that a substantial component of the black spruce landscape could be converted to hardwoods over the next 50-100 years.
LTER 3a (1998-2000): *Interaction of Multiple Disturbances with Climate in the Alaskan Boreal Forest*

**Task 4.** Document how the forest is changing due to changes in climate.

- Increased drought stress
- Reduced production of white spruce

![Smoothed mean annual temperature at Interior Alaska boreal forest stations](image1)

![20th century white spruce radial growth (20 stand mean) in relation to climate in Interior Alaska](image2)
Task 5. Document effects of climate and disturbance regime on productivity, biogeochemistry, and C cycling: At the stand level, C balance is controlled by vegetation & soil environment, and at the landscape scale by disturbance.
Task 6. Document the long-term record of climate, disturbance regime, vegetation, and ecosystem processes: Ecosystem response to climatic change depends on the state of each component of the system (climate, vegetation, and soils) and the susceptibility of individual processes to change.

The nature of stand replacement following disturbance is sensitive to climate and disturbance regime (reconstructing fire return intervals and vegetation across the landscape).

**LTER4a (2006-2010):** How are boreal ecosystems responding, both gradually and abruptly, to climate warming, and what new landscape patterns are emerging?

**4 Themes:**
- Climate Sensitivity
- Successional Dynamics
- Threshold Changes
- Integration and Synthesis

Integrating state factors, interactive controls, legacies, and resilience theory into ecosystem development and change (Chapin et al. 2006)

Societal consequences by identifying past and future changes in subsistence resources (provisioning services) and climate feedbacks (regulating services).

BNZ LTER framework for studying social-ecological systems
LTER4b (2004-2006): *The Dynamics of Change in Alaska’s Boreal Forests: Resilience and Vulnerability in Response to Climate Warming*

How are boreal ecosystems responding, both gradually and abruptly, to climate warming, and what new landscape patterns are emerging?

1) What currently controls and constrains the resilience of Alaska’s boreal forest?
2) What recent and projected changes in drivers make this system vulnerable to change?
3) How do factors influencing the balance among alternative states respond to recent and projected changes in drivers?

**3 Themes:**
- Forest Dynamics
- Biogeochemistry
- Landscape Dynamics

Integrating state factors, interactive controls, legacies, and resilience theory into ecosystem development and change (Chapin et al. 2006)

4 Themes:

- Climate Sensitivity
- Climate Disturbance Interactions
- Climate Feedbacks
- Social-Ecological Dynamics
BNZ LTER Regional Site Network

Monitoring Program:
- Climate, permafrost
- Vegetation composition
- Litterfall, ANPP
- Vertebrate herbivory
- Insects & pathogens

<table>
<thead>
<tr>
<th>Ecoregion</th>
<th>Area (km²)</th>
<th>Permafrost thickness</th>
<th>Permafrost stability</th>
<th>Parent material (bedrock)</th>
<th>Fire regime</th>
<th>Dominant vegetation</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Ray Mtns</td>
<td>51,243</td>
<td>Thin to moderate, across most of the region</td>
<td>Generally stable</td>
<td>Metaphorphic Ruby terrane</td>
<td>Occasional</td>
<td>Black spruce woodlands</td>
</tr>
<tr>
<td>Yukon-Tanana Uplands</td>
<td>102,496</td>
<td>Thin to moderate, depending on topography</td>
<td>Thin, ice-rich, and warm in valley bottoms and toeslopes.</td>
<td>Metasedimentary Yukon-Tanana terrane</td>
<td>Very frequent</td>
<td>Black spruce forests, black spruce woodlands, and black spruce bogs</td>
</tr>
<tr>
<td>Tanana-Kuskokwim Lowlands</td>
<td>51,730</td>
<td>Thin</td>
<td>Temperatures are near melting point</td>
<td>Alluvial, Fluvial, and glaciofluvial</td>
<td>Occasional, depending on site moisture</td>
<td>Boreal black spruce forests, black spruce bogs</td>
</tr>
</tbody>
</table>
LTER5 (2017-2023): Cross-Scale Controls Over Responses of the Alaskan Boreal Forest to Changing Disturbance Regimes

5 Themes:
- Climate Sensitivity
- Climate Disturbance Interactions
- Landscape Heterogeneity - Climate Feedbacks
- Social-Ecological Dynamics
- Resource Management Co-Production
LTER5 (2017-2023): *Cross-Scale Controls Over Responses of the Alaskan Boreal Forest to Changing Disturbance Regimes*

5 Themes:
- Climate Sensitivity
- Climate Disturbance Interactions
- Landscape Heterogeneity - Climate Feedbacks
- Social-Ecological Dynamics
- Resource Management Co-Production
Section IV: Social-ecological change and sources of resilience in subsistence villages of Interior Alaska
Assessing climate-driven alterations to human access to ecosystem services
Section V: Integrating LTER science and resource management with regional environmental change through co-production.

1) Develop coordinated science with agencies to fill key management knowledge gaps

2) Assess the outcomes of policy decisions with models that incorporate cross-scale feedbacks in the context of regional ecosystem dynamics

1) Communicate syntheses to policy makers in meaningful ways.
>90% of area burned over the past 60 years has been in interior boreal forests
1) What are the implications of changing successional dynamics for future fire behavior and fire management?

1) Document the impacts of alternate successional trajectories on the abundance and composition of fuels through succession for dominant vegetation types in interior Alaska

2) Develop new modeling tools to help managers predict fire vulnerability and spread

3) Estimate the landscape consequences of different scenarios of changing fire regimes and fire management on patterns of carbon sinks and sources in interior Alaska
2) Working with agencies to address complimentary objectives of landscape management

Understanding the fate and potential multiple-uses of fuel breaks in black spruce stands near homes and communities

Assessing opportunities for biofuels for boilers in rural communities (Fresco-PNW GTR)

Enhancing wildlife habitat for moose to improve food security in remote villages