Annual Report for Period: 02/2012 - 01/2013

Principal Investigator: Ruess, Roger W.
Organization: U of Alaska Fairbanks
Submitted By: Ruess, Roger - Principal Investigator

Title:
The Bonanza Creek (BNZ) LTER: Regional Consequences of Changing Climate-Disturbance Interactions for the Resilience of Alaska's Boreal Forest

Project Participants

Senior Personnel

<table>
<thead>
<tr>
<th>Name</th>
<th>Worked for more than 160 Hours</th>
<th>Contribution to Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ruess, Roger</td>
<td>Yes</td>
<td>BNZ LTER PI and lead of research on floodplain disturbance and succession</td>
</tr>
<tr>
<td>Jones, Jeremy</td>
<td>Yes</td>
<td>Leads work focusing on permafrost thaw and watershed hydrology and nutrient fluxes</td>
</tr>
<tr>
<td>Mack, Michelle</td>
<td>Yes</td>
<td>Heads research on post-fire biogeochemistry</td>
</tr>
<tr>
<td>McGuire, A. David</td>
<td>Yes</td>
<td>Leads synthesis modeling efforts focused on large-scale ecosystem dynamics and climate feedback pathways; supervisor of the BNZ data manager</td>
</tr>
<tr>
<td>Hollingsworth, Teresa</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Sparrow, Elena</td>
<td>Yes</td>
<td>BNZ Education and Schoolyard LTER Coordinator</td>
</tr>
<tr>
<td>Schuur, Edward</td>
<td>Yes</td>
<td>Leads the research on interactions between permafrost thaw and altered ecosystem carbon budgets</td>
</tr>
<tr>
<td>Johnstone, Jill</td>
<td>No</td>
<td>Leads research on post-fire successional trajectories (Tasks D3/D4); formerly LTER PhD student studying plant ecology</td>
</tr>
<tr>
<td>Verbyla, David</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>

Annual Report: 1026415
Submitted on: 01/23/2013
Award ID: 1026415
Contribution to Project:
Uses remotely sensed time series to determine trends in productivity (Task C1)

Name: Lloyd, Andrea
Worked for more than 160 Hours: Yes
Contribution to Project:
Leads paleoecological research

Name: Fastie, Chris
Worked for more than 160 Hours: Yes
Contribution to Project:
Lead field research in paleoecological

Name: Valentine, David
Worked for more than 160 Hours: Yes
Contribution to Project:
Studies soil carbon and nutrient dynamics, particularly as a function of changing moisture

Name: Euskirchen, Eugenie
Worked for more than 160 Hours: No
Contribution to Project:
Co-lead on the regional ecosystem dynamics and climate feedbacks section of this LTER grant

Name: Harden, Jennifer
Worked for more than 160 Hours: Yes
Contribution to Project:
Leads LTER research in wetland carbon cycling and biogeochemistry

Name: Yarie, John
Worked for more than 160 Hours: Yes
Contribution to Project:
Senior investigator studying tree growth dynamics

Name: Wagner, Diane
Worked for more than 160 Hours: Yes
Contribution to Project:
Studies herbivory, plant performance, plant defense.

Name: Turetsky, Merritt
Worked for more than 160 Hours: Yes
Contribution to Project:
Studies vegetation and carbon cycling in peatlands

Name: Taylor, Lee
Worked for more than 160 Hours: Yes
Contribution to Project:
Leads LTER research on microbial role in plant community dynamics

Name: Juday, Glenn
Worked for more than 160 Hours: Yes
Contribution to Project:
Leads LTER dendroecological research, focusing on climatic and insect controls over tree growth

Name: Kasischke, Eric
Worked for more than 160 Hours: Yes
Contribution to Project:
Conducts research on changing boreal forest fire regimes

Name: Kielland, Knut

Worked for more than 160 Hours: Yes

Contribution to Project:
Leads LTER research on mammals and mammalian herbivory, and conducts research on the role of organic nitrogen in the boreal N cycle

Name: Kofinas, Gary

Worked for more than 160 Hours: Yes

Contribution to Project:
Leads LTER research on human dimensions of subsistence

Name: Leigh, Mary Beth

Worked for more than 160 Hours: Yes

Contribution to Project:
Leads the integration of LTER science with arts and humanities and public outreach; researches soil microbiology

Name: Mulder, Christa

Worked for more than 160 Hours: Yes

Contribution to Project:
Leads LTER research on pland diseases, including environmental controls and ecological consequences

Name: Romanovsky, Vladimir

Worked for more than 160 Hours: Yes

Contribution to Project:
Leads permafrost modeling for LTER

Name: Rupp, Scott

Worked for more than 160 Hours: Yes

Contribution to Project:
Leads landscape modeling of the LTER program and coordinates scientific outreach on climate change projections and impacts on boreal forest to agencies and NGOs

Name: Waldrop, Mark

Worked for more than 160 Hours: No

Contribution to Project:
Leads LTER research in wetland carbon cycling and biogeochemistry

Name: Ewing, Stephanie

Worked for more than 160 Hours: No

Contribution to Project:
Collaborator

Name: Jones, Miriam

Worked for more than 160 Hours: No

Contribution to Project:
Collaborator

Name: Shur, Yuri

Worked for more than 160 Hours: No

Contribution to Project:
Collaborator

Name: Wickland, Kim

Worked for more than 160 Hours: No

Contribution to Project:
Collaborator

Name: Jansson, Janet
Worked for more than 160 Hours: No
Contribution to Project: collaborator, genomics

Post-doc

Name: Bracho, Rosvel
Worked for more than 160 Hours: Yes
Contribution to Project:
Assisted with the field component of this project in particular with maintenance and processing of the eddy covariance data. Research supported in part by this grant.

Name: Natali, Susan
Worked for more than 160 Hours: Yes
Contribution to Project:
Post-doc studying ecosystem effects of climate change (UFL)

Name: Harms, Tamara
Worked for more than 160 Hours: Yes
Contribution to Project:
Conducted study examining factors controlling nitrogen loss from soils

Name: Yuan, Fengming
Worked for more than 160 Hours: Yes
Contribution to Project:
Modeling research on biogeochemical cycling of forest ecosystems in interior Alaska

Name: Fan, Zhaosheng
Worked for more than 160 Hours: Yes
Contribution to Project:
Modeling research on biogeochemical cycling of peatland ecosystems in interior Alaska

Name: Genet, Helene
Worked for more than 160 Hours: Yes
Contribution to Project:
Modeling research on forest vegetation dynamics in interior Alaska

Name: Grant, Thomas III
Worked for more than 160 Hours: Yes
Contribution to Project:
Field data collection, Proposal preparation, database design, dendrochronology investigation

Name: Alexander, Heather
Worked for more than 160 Hours: Yes
Contribution to Project:
Led survey of productivity and structure of intermediate aged stands in boreal forest

Name: Reiskind, Julia
Worked for more than 160 Hours: Yes
Contribution to Project:
Directed lab work (Mack)

Name: Breen, Amy
Worked for more than 160 Hours: No
Contribution to Project:
Leading ALFRESCO development of tundra vegetation dynamics and wildfire
Name: Coe, Kirsten
Worked for more than 160 Hours: Yes

Contribution to Project:
Post-doc studying ecosystem effects of climate change (UFL)
Name: LaCroix, Jacob
Worked for more than 160 Hours: No

Contribution to Project:
Modeling climate change impacts on wildlife habitat
Name: Melvin, April
Worked for more than 160 Hours: No

Contribution to Project:
Led experimental study of controls over productivity and decomposition in intermediate-aged stands; led study of fuel management effects on soil processes
Name: Schmidt, Jennifer
Worked for more than 160 Hours: No

Contribution to Project:
Modeling disturbance impacts on wildlife habitat
Name: Sierra, Carlos
Worked for more than 160 Hours: No

Contribution to Project:
Collaborator
Name: Zhang, Yujin
Worked for more than 160 Hours: Yes

Contribution to Project:
Modeling research on ecosystem transitions in response to thermokarst disturbance
Name: Petersen, Dorthe
Worked for more than 160 Hours: Yes

Contribution to Project:
field and lab studies, soil microbiology
Name: Hultman, Jenni
Worked for more than 160 Hours: No

Contribution to Project:
collaborator, genomics

Graduate Student
Name: Baron Lopez, Andres
Worked for more than 160 Hours: Yes

Contribution to Project:
Worked in the field during the spring of 2011 as part of this project. Past REU undergraduate who is continuing a master's degree at UF on a related project.
Name: Belshe, Fay
Worked for more than 160 Hours: Yes

Contribution to Project:
Returning student who is taking the lead on eddy covariance measurements in the field and on spatial analysis of thermokarst using remote sensing. Supported by a Department of Energy fellowship; research activities supported by this grant.
Name: Hicks Pries, Caitlin  
**Worked for more than 160 Hours:** Yes  
**Contribution to Project:**  
Returning student who is taking the lead on measurements of radiocarbon in soil organic matter pools, and stable carbon isotope measurements of plant and soil respiration. Supported by an Alumni Fellowship from the University of Florida; research activities supported by this grant.

Name: Nossov, Dana  
**Worked for more than 160 Hours:** Yes  
**Contribution to Project:**  
PhD student studying permafrost; former LTER lab manager and research technician; formerly LTER MS student studying plant ecology

Name: Trucco, Christian  
**Worked for more than 160 Hours:** Yes  
**Contribution to Project:**  
Responsible for assisting with field data collection and infrastructure. Worked closely with Schuur and Natali. Supported in part by this grant. Formerly technician and MS student. Graduated Spring 2011.

Name: Webb, Elizabeth  
**Worked for more than 160 Hours:** Yes  
**Contribution to Project:**  
New student who is taking the lead on winter carbon flux measurements

Name: Walker, Xanthe  
**Worked for more than 160 Hours:** Yes  
**Contribution to Project:**  
Ph.D. student, conducting research on climate-growth relationships and post-fire resilience

Name: Frey, Matthew  
**Worked for more than 160 Hours:** No  
**Contribution to Project:**  
MSc student, testing disturbance effects on plant species invasion

Name: Shenoy, Aditi  
**Worked for more than 160 Hours:** Yes  
**Contribution to Project:**  
Ph.D. student, effects of fire severity on succession & biogeochemistry

Name: Parent, Mary Beth  
**Worked for more than 160 Hours:** Yes  
**Contribution to Project:**

Name: Baird, Becky  
**Worked for more than 160 Hours:** Yes  
**Contribution to Project:**

Name: Rinehart, Amanda  
**Worked for more than 160 Hours:** Yes  
**Contribution to Project:**  
Conducted dissertation research examining effects of permafrost on stream-riparian interactions, assisted with stream discharge and chemistry monitoring

Name: Olsson, Ann  
**Worked for more than 160 Hours:** Yes
Contribution to Project:
Conducted dissertation research examining effects of wildfire on watershed nutrient exports, assisted with stream discharge and chemistry monitoring
Name: Churchill, Amber
Worked for more than 160 Hours: Yes

Contribution to Project:
M.S. research on primary production in boreal peatlands
Name: McConnell, Nicole
Worked for more than 160 Hours: Yes

Contribution to Project:
M.S. research on ecosystem respiration in boreal peatlands
Name: Schwing, Emily
Worked for more than 160 Hours: Yes

Contribution to Project:
Influence of soil moisture stress on allocation of carbon belowground and partitioning of soil respiration
Name: Carman, Tobey
Worked for more than 160 Hours: No

Contribution to Project:
MS student in computer science implementing a leaf phenology algorithm into the Terrestrial Ecosystem Model
Name: Patil, Vijay
Worked for more than 160 Hours: No

Contribution to Project:
PhD student studying vegetation dynamics surrounding areas with lake change in boreal Alaska
Name: Klapstein, Sara
Worked for more than 160 Hours: Yes

Contribution to Project:
Graduate student studying soil methane emissions
Name: Glass, Dan
Worked for more than 160 Hours: Yes

Contribution to Project:
Analyzed novel fungal lineages recovered from Bonanza Creek soils
Name: Carroll, Cameron
Worked for more than 160 Hours: Yes

Contribution to Project:
MS student, fire effects on moose browsing
Name: Denniss, Russell
Worked for more than 160 Hours: Yes

Contribution to Project:
MS student, plant-insect interactions of aspen leaf miner
Name: DeWilde, La'ona
Worked for more than 160 Hours: Yes

Contribution to Project:
Studies contaminants in Alaskan streams; development of adopt-a-stream program
Name: Feierabend, Dashiell
Worked for more than 160 Hours: Yes

Contribution to Project:
MS student, predator-prey interactions of lynx and snowshoe hares
Name: Hewitt, Rebecca
Worked for more than 160 Hours: Yes
Contribution to Project:
PhD student, the role of mycorrhizae in post-fire plant succession
Name: Julianus, Erin
Worked for more than 160 Hours: Yes
Contribution to Project:
MS student, linking fire history to moose populations in Kanuti National Wildlife Refuge
Name: Maher, Kimberley
Worked for more than 160 Hours: Yes
Contribution to Project:
Dendrochronology measurement and analysis
Name: Peterson, Randy
Worked for more than 160 Hours: Yes
Contribution to Project:
Field data collection, database design
Name: Swanson, Michaela
Worked for more than 160 Hours: Yes
Contribution to Project:
MS student, coupling nitrogen fixation and phosphorous biogeochemistry
Name: Tape, Ken
Worked for more than 160 Hours: Yes
Contribution to Project:
PhD graduate, shrub distribution and expansion in northern Alaska
Name: Vargas-Kretsinger, Delia
Worked for more than 160 Hours: Yes
Contribution to Project:
MS student, early successional dynamics of Yukon River floodplains
Name: Winterstein, Mark
Worked for more than 160 Hours: Yes
Contribution to Project:
Name: Worker, Suzanne
Worked for more than 160 Hours: Yes
Contribution to Project:
MS student, snowshoe hare response to climate-mediated changes in plant toxicity
Name: Leewis, Mary-Cathrine
Worked for more than 160 Hours: Yes
Contribution to Project:
PhD student, soil microbiology
Name: Burgess, Robert
Worked for more than 160 Hours: Yes
Contribution to Project:
MS student, soil microbiology
Name: de Roo, Colette
Worked for more than 160 Hours: Yes
Contribution to Project:
PhD student researcher studying vulnerability to changing seasonality and modeling SES dynamics

Name: Allman, Brian
Worked for more than 160 Hours: Yes
Contribution to Project:
MS student, consequences of vertebrate and invertebrate herbivory for willow

Name: Baker, Christina
Worked for more than 160 Hours: Yes
Contribution to Project:
Conducted dissertation research examining consumer effects on streams

Name: Brown, Casey
Worked for more than 160 Hours: Yes
Contribution to Project:
PhD student studying moose movement and browse availability across burn sites in interior Alaska

Name: Dorich, Chris
Worked for more than 160 Hours: No
Contribution to Project:
Collaborator

Name: Durrett, Melody
Worked for more than 160 Hours: No
Contribution to Project:
Consequences of insect outbreak for willow

Name: Finger, Rebecca
Worked for more than 160 Hours: Yes
Contribution to Project:
Field studies of N cycling related to permafrost thaw

Name: Fjare, Dana
Worked for more than 160 Hours: Yes
Contribution to Project:
Conducted thesis research examining stream nutrient spiraling

Name: Hansen, Winslow
Worked for more than 160 Hours: No
Contribution to Project:
Researching linked disturbance regimes

Name: He, Yujie
Worked for more than 160 Hours: No
Contribution to Project:
Collaborator

Name: Johnson, Carmel
Worked for more than 160 Hours: No
Contribution to Project:
Collaborator

Name: McClung, Simon
Worked for more than 160 Hours: No
**Contribution to Project:**
Led study of lodgepole pine effects on ecosystem processes

**Name:** Spellman, Katie

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
PhD student working on invasive plants and competition for pollinators with native plants

**Name:** Timling, Ina

**Worked for more than 160 Hours:** No

**Contribution to Project:**
Analysis of fungal community composition in the Arctic

**Name:** Jones, Chas

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
Ph.D. student, hydrology and ice physics

**Name:** Estruch, Carme

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
Field assistant

**Undergraduate Student**

**Name:** Rubin, Rachel

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
Worked in the field during the summer of 2010 as part of a University Scholar’s Research Program at the University of Florida. She collected data that is now part of her senior honors project; graduated Spring 2011.

**Name:** Young, Nathan

**Worked for more than 160 Hours:** No

**Contribution to Project:**
Assisted with research on post-fire successional trajectories (Task D3)

**Name:** Jaeger, Margit

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
Assisted with stream discharge and chemistry monitoring

**Name:** Gobroski, Kelsey

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
Undergraduate working with the Forest Soils Lab

**Name:** Wiseman, Michele

**Worked for more than 160 Hours:** No

**Contribution to Project:**
Summer assistant in Taylor lab. Collected and processed seedlings from burn sites for mycorrhizal study.

**Name:** Petronio, Brandi Jo

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
Assisted with fieldwork and labwork (Mack)

**Name:** Huang, Hailun
Worked for more than 160 Hours: Yes
Contribution to Project: Assisted with fieldwork and labwork (Mack)
Name: Ganzlin, Peter

Worked for more than 160 Hours: Yes
Contribution to Project: Worked in the field during the summer and fall of 2012 as a field technician. Also REU for M. Mack.
Name: Baalim, Fraser

Worked for more than 160 Hours: Yes
Contribution to Project: Assisted with research on vegetation sensitivity to climate change and impacts of fire severity
Name: Bourque, Tanis

Worked for more than 160 Hours: Yes
Contribution to Project: Consequences of insect outbreak for willow
Name: Hakala, Jacob

Worked for more than 160 Hours: Yes
Contribution to Project: Working with the Forest Soils Lab on LTER related tasks
Name: Izaguirre, Natalie

Worked for more than 160 Hours: No
Contribution to Project: Assisted with labwork (Mack)
Name: Louis, Randell

Worked for more than 160 Hours: No
Contribution to Project: Assisted with labwork (Mack)
Name: Nelson, Jamia

Worked for more than 160 Hours: No
Contribution to Project: Assisted with labwork (Mack)
Name: Panos, Demetra

Worked for more than 160 Hours: No
Contribution to Project: Assisted with fieldwork and labwork (Mack)
Name: Pegoraro, Elaine

Worked for more than 160 Hours: Yes
Contribution to Project: Student and laboratory technician, responsible for the laboratory processing of field samples. Also completed an honors project on litter quality
Name: Sendrowski, Alicia

Worked for more than 160 Hours: No
Contribution to Project: Assisted with labwork (Mack)
Name: Tales, Carolyn

Worked for more than 160 Hours: No
Contribution to Project:
Assisted with labwork (Mack)

Name: Taylor-Hoar, Kira
Worked for more than 160 Hours: No

Contribution to Project:
Assisted with fieldwork and labwork (Mack)

Technician, Programmer

Name: Crummer, Grace
Worked for more than 160 Hours: Yes
Contribution to Project:
Directed lab work (Mack)

Name: Hollingsworth, Jamie
Worked for more than 160 Hours: Yes
Contribution to Project:
BNZ LTER Site Manager

Name: Charlton, Brian
Worked for more than 160 Hours: Yes
Contribution to Project:
BNZ LTER research technician

Name: Corley, Lyndsey
Worked for more than 160 Hours: Yes
Contribution to Project:
BNZ LTER seasonal research technician

Name: Nichols, Courtney
Worked for more than 160 Hours: Yes
Contribution to Project:
BNZ LTER seasonal research technician

Name: Lawrence, Caitlin
Worked for more than 160 Hours: Yes
Contribution to Project:
BNZ LTER seasonal research technician

Name: Kranich, Kathleen
Worked for more than 160 Hours: Yes
Contribution to Project:
seasonal research technician for Forest Inventory and Analysis program

Name: Shew, Erin
Worked for more than 160 Hours: Yes
Contribution to Project:
seasonal research technician for Forest Inventory and Analysis program

Name: Frost, Shalane
Worked for more than 160 Hours: Yes
Contribution to Project:
LTER lab manager and research technician

Name: Downing, Jason
Worked for more than 160 Hours: Yes
Contribution to Project:
BNZ LTER Data Manager
Name: Tissier, Emily
Worked for more than 160 Hours: Yes
Contribution to Project:
Short-term research technician, Assisted with research on the effects of fire regimes on successional trajectories

Name: Charry, Bertrand
Worked for more than 160 Hours: Yes
Contribution to Project:
Short-term technician, Assisted with research on post-fire successional trajectories

Name: Blumstein, Megan
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Cable, William
Worked for more than 160 Hours: Yes
Contribution to Project:
Maintains manipulations and data logging equipment in the Alaska Peatland Experiment

Name: Robertson, Matthew
Worked for more than 160 Hours: Yes
Contribution to Project:
Field site maintenance

Name: Oliver, Lola
Worked for more than 160 Hours: Yes
Contribution to Project:
Laboratory Technician for LTER and McIntire Stennis projects

Name: Quintal, Tim
Worked for more than 160 Hours: Yes
Contribution to Project:
Data acquisition and management

Name: Olson, Karl
Worked for more than 160 Hours: Yes
Contribution to Project:
Research technician (mammal populations, herbivory, and biogeochemistry)

Name: Spencer, David
Worked for more than 160 Hours: Yes
Contribution to Project:
Field data collection, Tree Ring Lab Manager, database design and entry

Name: Manies, Kirsten
Worked for more than 160 Hours: No
Contribution to Project:
Sample and data collection; data synthesis

Name: Avera, Bethany
Worked for more than 160 Hours: No
Contribution to Project:
Assisted with fieldwork and labwork
<table>
<thead>
<tr>
<th>Name</th>
<th>Worked for more than 160 Hours</th>
<th>Contribution to Project</th>
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</thead>
<tbody>
<tr>
<td>Bennett, Alec</td>
<td>No</td>
<td>Lead programmer for the ALFRESCO model</td>
</tr>
<tr>
<td>Berner, Logan</td>
<td>No</td>
<td>Assisted with fieldwork and labwork (Mack)</td>
</tr>
<tr>
<td>Herriott, Ian</td>
<td>No</td>
<td>General lab management in Taylor lab</td>
</tr>
<tr>
<td>Ponchione, Luke</td>
<td>Yes</td>
<td>field and lab work</td>
</tr>
<tr>
<td>Richards, Keane</td>
<td>Yes</td>
<td>Consequences of vertebrate and invertebrate herbivory for willow</td>
</tr>
<tr>
<td>Haw, Monica</td>
<td>Yes</td>
<td>Lab technician</td>
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<td>Blazewicz, Steve</td>
<td>Yes</td>
<td>field and lab studies, soil microbiology</td>
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<td>Rychel, Cate</td>
<td>Yes</td>
<td>Lab technician</td>
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<tr>
<td>Kabariti, Joanne</td>
<td>Yes</td>
<td>Lab technician</td>
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<tr>
<td>White, Richard</td>
<td>Yes</td>
<td>Lab technician</td>
</tr>
<tr>
<td>Sevilgen, Sabrina</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Cohen, Lily</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>
Contribution to Project:
Field assistant
Name: O'Neal, Naomi
Worked for more than 160 Hours: Yes
Contribution to Project:
conducting interviews

Other Participant
Name: Adema, Guy
Worked for more than 160 Hours: No
Contribution to Project:
Collaborator from Denali National Park and Preserve, Long Term Monitoring Program
Name: Schimel, David
Worked for more than 160 Hours: No
Contribution to Project:
Collaborator from National Ecological Observation Network
Name: Southon, John
Worked for more than 160 Hours: No
Contribution to Project:
Collaborator from Keck Carbon Cycle Accelerator Mass Spectrometry facility at the University of California, Irvine
Name: Xu, Xiaomei
Worked for more than 160 Hours: No
Contribution to Project:
Collaborator from Keck Carbon Cycle Accelerator Mass Spectrometry facility at the University of California, Irvine
Name: Barrett, Kirsten
Worked for more than 160 Hours: Yes
Contribution to Project:
Remote sensing research on fire severity and vegetation dynamics in interior Alaska
Name: Brinkman, Todd
Worked for more than 160 Hours: Yes
Contribution to Project:
Integrating local / traditional knowledge with best available science to model SES dynamics; PhD graduate
Name: Meek, Chanda
Worked for more than 160 Hours: Yes
Contribution to Project:
Conducting institutional analysis related to Social Ecological Systems
Name: Chapin, F. Stuart
Worked for more than 160 Hours: Yes
Contribution to Project:
Former BNZ LTER PI and lead of the task on ecosystem services; currently affiliate LTER investigator
Name: Anderson, Mike
Worked for more than 160 Hours: Yes
Contribution to Project:
Affiliate scientist and PhD graduate: variation in the Alnus-Frankia interaction
Name: Barber, Valerie
Worked for more than 160 Hours: No
Contribution to Project:
Affiliate scientist, tree ring analysis
Name: Bret-Harte, Sydonia
Worked for more than 160 Hours: No

Contribution to Project:
Affiliate scientist, plant physiological ecologist
Name: Brown, Caroline
Worked for more than 160 Hours: No

Contribution to Project:
Affiliate scientist, wildfire impacts on subsistence, Alaska Dept of Fish & Game
Name: Cahill, Cathy
Worked for more than 160 Hours: No

Contribution to Project:
Affiliate scientist, atmospheric science
Name: Calef, Monika
Worked for more than 160 Hours: No

Contribution to Project:
Affiliate scientist, landscape dynamics of human-fire interactions
Name: Doak, Pat
Worked for more than 160 Hours: No

Contribution to Project:
Affiliate scientist, leaf miner outbreak
Name: Duffy, Paul
Worked for more than 160 Hours: No

Contribution to Project:
Affiliate scientist, modeling fire regime
Name: Edwards, Mary
Worked for more than 160 Hours: No

Contribution to Project:
Affiliate scientist, paleolimnology of lakes
Name: Illman, Barbara
Worked for more than 160 Hours: No

Contribution to Project:
Affiliate scientist, entomology
Name: Jandt, Randi
Worked for more than 160 Hours: No

Contribution to Project:
Affiliate scientist, fire ecology
Name: Jorgenson, Torre
Worked for more than 160 Hours: No

Contribution to Project:
Affiliate scientist, permafrost studies, Alaska Ecoscience
Name: Kruse, Jim
Worked for more than 160 Hours: No

Contribution to Project:
Affiliate scientist; Interior Forest Entomologist, USFS Region 10, State and Private Forestry, Fairbanks
Name: Laursen, Gary  
Worked for more than 160 Hours: No  
Contribution to Project: Affiliate scientist, fungal ecology

Name: Okada, Yasutaka  
Worked for more than 160 Hours: No  
Contribution to Project: Affiliate scientist, Hokkaido University

Name: Osterkamp, Tom  
Worked for more than 160 Hours: No  
Contribution to Project: Affiliate scientist, Geophysical Institute

Name: Ottmar, Robert  
Worked for more than 160 Hours: No  
Contribution to Project: Affiliate scientist, fire behavior

Name: Ping, Chien-Lu  
Worked for more than 160 Hours: No  
Contribution to Project: Affiliate scientist, soil science

Name: Riche, Kathie  
Worked for more than 160 Hours: No  
Contribution to Project: Affiliate scientist, Caribou Rocket Range

Name: Schimel, Joshua  
Worked for more than 160 Hours: No  
Contribution to Project: Affiliate scientist, microbial ecology

Name: Sveinbjornsson, Bjartmar  
Worked for more than 160 Hours: No  
Contribution to Project: Affiliate scientist

Name: Tanaka, Yasuyoshi  
Worked for more than 160 Hours: No  
Contribution to Project: Affiliate scientist, Geophysical Institute

Name: Urano, Shin-ichi  
Worked for more than 160 Hours: No  
Contribution to Project: Affiliate scientist, data management

Name: Vogel, Jason  
Worked for more than 160 Hours: No  
Contribution to Project: Affiliate scientist, ecosystem studies, former post-doc

Name: Werner, Richard  
Worked for more than 160 Hours: No
Contribution to Project:
Affiliate scientist, insect population dynamics, retired senior investigator

Name: Yoshikawa, Kenji
Worked for more than 160 Hours: No

Contribution to Project:
Affiliate scientist, permafrost science

Name: Zasada, John
Worked for more than 160 Hours: No

Contribution to Project:
Affiliate scientist, forest products

Name: Adams, Gerard
Worked for more than 160 Hours: No

Contribution to Project:
Plant Pathologist, Michigan State University

Name: DiFolco, Donna
Worked for more than 160 Hours: No

Contribution to Project:
Collaborator on Task C4 (vertebrate herbivore abundance) from NPS, Gates of the Arctic National Park

Name: Forbey, Jen
Worked for more than 160 Hours: No

Contribution to Project:
Collaborator on Task C4 (vertebrate herbivore abundance) from Boise State University

Name: Koyama, Lina
Worked for more than 160 Hours: No

Contribution to Project:
Collaborator on Task C4 (vertebrate herbivore abundance) from Kyoto University

Name: Marchenko, Sergei
Worked for more than 160 Hours: No

Contribution to Project:
Collaborator from Geophysical Institute (UAF)

Name: Persson, Inga-Lill
Worked for more than 160 Hours: No

Contribution to Project:
Collaborator on Task C4 from Swedish University of Agricultural Sciences

Name: Stanosz, Glen
Worked for more than 160 Hours: No

Contribution to Project:
Forest Pathologist, University of Wisconsin

Name: Winton, Lori
Worked for more than 160 Hours: No

Contribution to Project:
Forest Pathologist, USFS Region 10, State and Private Forestry, Anchorage

Name: Zogas, Ken
Worked for more than 160 Hours: No

Contribution to Project:
Alaska Insect and Disease Aerial Detection, USFS Region 10, State and Private Forestry, Anchorage
Name: Goetz, Scott
Worked for more than 160 Hours:  No
Contribution to Project:  
Led remote sensing of intermediate-aged and mature stands

Name: Hansen, Thomas
Worked for more than 160 Hours:  No
Contribution to Project:  
Led molecular characterization of moss-associated diazotrophs in black spruce forests

Name: Jafarov, Elchin
Worked for more than 160 Hours:  No
Contribution to Project:  
Collaborator from Geophysical Institute (UAF)

Name: Jaffe, Rudolf
Worked for more than 160 Hours:  No
Contribution to Project:  
Collaborated on study of black carbon in streams

Name: McDaniels, Stuart
Worked for more than 160 Hours:  Yes
Contribution to Project:  
Led molecular characterization of moss population genetics and diazotroph diversity in black spruce forests

Name: Varner, Ruth
Worked for more than 160 Hours:  No
Contribution to Project:  
Collaborator

Name: McFarland, Jack
Worked for more than 160 Hours:  Yes
Contribution to Project:  
Affiliate scientist, ecologist

Research Experience for Undergraduates

Name: Majoica, Camilo
Worked for more than 160 Hours:  Yes
Contribution to Project:  
Assisted with fieldwork and labwork (Mack)

Name: Earl, Kamala
Worked for more than 160 Hours:  Yes
Contribution to Project:  

Name: Johnstone, Catherine
Worked for more than 160 Hours:  Yes
Contribution to Project:  
Worked in the field during the summer and fall of 2012 as part of the REU program.

Name: Smith, Matthew
Worked for more than 160 Hours:  Yes
Contribution to Project:  
Consequences of vertebrate and invertebrate herbivory for willow
Organizational Partners

USDA Forest Service- PNW
The U.S. Forest Service maintains a research unit, the Boreal Ecology Cooperative Research Unit, on the UAF campus with a mission of promoting understanding of key ecological relations determining the response of wild lands to climate change and land management activities in Alaska. Its principal means of working toward that mission is through its active participation in the Bonanza Creek Long-Term Ecological Research Program. The research unit consists of 3 full-time scientists and one professional series biologist. The contribution to BNZ LTER is 2.75 full-time scientists plus their operating budgets and a direct contribution of about $180,000 per year to BNZ LTER through a Research Joint Venture Agreement with UAF. Total Forest Service contributions to BNZ LTER amount to approximately $690,000 annually. Collaborative research is conducted with other LTER scientists and state and federal agencies through collaboration in competitive grants and through a variety of federal Research Joint Venture Agreements.

That said, we are concerned about the recent declines and overall instability of the USFS support for the BNZ LTER program. The USFS has played a prominent role in forest ecosystem/forest management research in interior Alaska for over 30 years, and remains a central collaborator in the BNZ LTER program. Although the financial support from the USFS ($182,000/year) constitutes only 16% of the total program support, it provides critical infrastructure required for maintaining long-term experiments and climate monitoring. This includes a variety of long-term hydrological and vegetation monitoring, and climate stations with long-term data used by a diverse group of stake-holders. Moreover, USFS provides salary for Teresa Hollingsworth, who serves as a co-PI of the project; thus, we have always viewed USFS and NSF as equal partners.

However, the USFS commitment to the BNZ LTER was reduced by approximately 10% in FY11 and we have recently learned from Tom Hanley that USFS support will be reduced by $32,000 in FY12 (-18%). Most of the NSF funds and all the USFS funds are used to support infrastructure (data management, site management, long-term experiment and monitoring, etc.). Senior scientists receive only modest direct support (up to $25,000/year), but are expected to use those funds to leverage additional outside support. The BNZ LTER has been exceptionally successful in this regard; the ratio of outside support from additional grants to direct NSF support is approximately 7:1. Given the need to maintain critical baseline infrastructure, USFS cuts will directly impact support to scientists, including Teresa Hollingsworth, and thus the funds that they have so successfully leveraged.

We recognize the difficult challenges the PNW office is likely facing as USFS budgets are being squeezed nation-wide. PNW supports a broad range of highly talented scientists and programs. The profile of the USFS in Fairbanks is perhaps higher now than it ever has been because of the relevance of BNZ LTER/USFS science to land and wildlife managers and resource policy makers at a time when changing climate and disturbance regimes are rapidly reshaping the boreal forest landscape. However, we are very concerned that changes to the long-term USFS support of the BNZ LTER will have serious implications for the research program. No final budget decisions for FY13 USFS funding have been made yet. We are talking closely with USFS PNW administration and emphasizing the strengths of both BNZ and AND to the long-term mission of the USFS.

Denali National Park and Preserve
Collaboration with Long Term Monitoring Program

University of California, Irvine
Collaboration with Keck Carbon Cycle Accelerator Mass Spectrometry facility

National Ecological Observation Network

University of Saskatchewan
Home institution for Johnstone and students; venue for collaborative research on Canadian and Alaskan boreal forests.

US Geological Survey
Home institution of Harden, provides support for McGuire, and collaborates on many projects with various personnel
Arctic Research Consortium of the U.S.  
Hosted two webinars during the 2011 Mt Kilimanjaro Expedition for students and teachers participating virtually online, in the study of biomes on Mt Kilimanjaro as well as the biomes where their schools are.

Gates of the Arctic National Park

Boise State University

Kyoto University

Swedish Univ of Agricultural Science

Geophysical Institute

University of Wisconsin

Michigan State University

Alaska Division of Forestry  
Provides land for the major research site through a 30-year lease to the USDA Forest Service; shares in road maintenance

Bureau of Land Management  
Owns some of the land at the Caribou-Poker Creeks Research Watershed, which is managed by University of Alaska. Also has helped fund individual projects.

Middlebury College  
Home institution of Lloyd and Fastie

University of Florida  
Home institution of Schuur, Mack, and their students

University of Maryland  
Home institution of Kasischke

Arctic Region Supercomputing Center  
The supercomputer staff have assisted in database development and archival

US Fish & Wildlife Service

US National Park Service

BLM - Alaska Fire Service

Yukon Flats National Wildlife Refuge

Kanuti National Wildlife Refuge

Alaska Ecosciences
Fairbanks North Star Borough School District
We maintain a partnership with the school district and local schools for our Schoolyard LTER programs

Florida International University

University of Delaware
This is the home institution of Mack's collaborator Thomas Hansen

Woods Hole Research Institute
This is the home institution of Mack's collaborator Scott Goetz

University of Texas at Brownsville
This is the home institution of Mack's collaborator and past postdoc, Heather Alexander

The University of Montana
Ebullition, biogeochemistry, student co-mentorship with Harden

University of New Hampshire
Ebullition and dissolved biogeochemistry

Max Planck Institute for Biogeochemistry
Soil radiocarbon

Globe Research and Education Foundation
infrastructure

International Arctic Research Center

Department of Interior National Park Service

Other Collaborators or Contacts

Activities and Findings

Research and Education Activities: (See PDF version submitted by PI at the end of the report)
see attached file

Findings: (See PDF version submitted by PI at the end of the report)
see attached file

Training and Development:
this section is appended to the Activities section

Outreach Activities:
This section is appended to the Activities Section

Journal Publications
Adger, W.N.; Barnett, J.; Chapin III, F.S.; Ellemor, H.; "This must be the place: Underrepresentation of identity and meaning in climate change decision-making", Global Environmental Politics, p. 1-25, vol. 11, (2011). Published,


Grosse, G.; Romanovsky, V.E.; Jorgenson, M.T.; Walter, K.; Brown, J.; Overduin, P.P.; "Vulnerability and feedbacks of permafrost to climate change", EOS, p. 73-80, vol. 92, (2011). Published,


Huntington, H.P.; Goodstein, E.; Euskirchen, E.S.; "Towards a tipping point in responding to change: Rising costs, fewer options for arctic and global societies", Ambio, p. 66-74, vol. 41, (2012). Published,

Huntzinger, D.N.; Post, W.; Wei, Y.; Michalak, A.M.; West, T.O.; Jacobson, A.; Baker, I.T.; Chen, J.M.; Davis, K.; Hayes, D.J.; Hoffman,

Jafarov, E.E.; Marchenko, S.; Romanovsky, V.E.; "Dynamics in Alaska using a high spatial resolution dataset", The Cryosphere, p. 89-124, vol. 6, (2012). Published,


nitrogen cycling as indices of biogeochemical process rates across a vegetation gradient in Alaska", Environmental Microbiology, p. 993-1008, vol. 14, (2012). Published,

Reiskind, J.B.;Mack, M.C.;Lavoie, M.; "Kinetic studies of proteolytic enzyme activity of Arctic soils under varying toluene concentrations", Soil Biology and Biochemistry, p. 70-77, vol. 43, (2011). Published,


Timling, I.;Dahlberg, A.;Gardes, M.;Walter, D.A.;Taylor, D.L.; "Diverse ectomycorrhizal fungal communities of Salix arctica and Dryas integrifolia are widely distributed outside as well as across the Arctic", Ecosphere, p. , vol. , (2012). Accepted,


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Books or Other One-time Publications

Anderson, M. D., "Two in the far north: the alder-Frankia symbiosis, with an Alaskan case study.", (2011). book section, Published
Editor(s): J. C. Polacco and C. D. Todd

Bibliography: MS Thesis. University of Alaska Fairbanks, Fairbanks

Editor(s): A. L. Lovecraft and H. Eicken


Hayes, D. J., A. D. McGuire, D. W. Kicklighter, T. J. Burnside, and J.M. Melillo, "The effects of land cover and land use change on the
contemporary carbon balance of the arctic and boreal ecosystems of northern Eurasia", (2011). book section, Published
Editor(s): G. Gutman and A. Reissell

Editor(s): G. Gutman and A. Reissell

Leigh, M. B., K. Katalenich, C. Hardy, and P. Kohler, "Climate Change and Creative Expression", (2011). book section, Published

Bibliography: University Corporation for Atmospheric Research

Bibliography: MS Thesis. University of Alaska Fairbanks, Fairbanks

Editor(s): X. Jin-Rong and H. B. Burton


Editor(s): R.J. Hobbs, E.S. Higgs, and C.M. Hall

Editor(s): El-Shaarawi A.H., Piegorsch W.W.

Editor(s): P.Ya. Groisman and G. Gutman

Editor(s): R. Lal, K. Lorenz, R.F. Huttl, B.U. Schneider, and J. von Braun

Editor(s): C. Symon, H. Thing and J. Pawlak
Bibliography: Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway, pp. 5.1-5.62
Bibliography: http://www.arctic.noaa.gov/reportcard

Bibliography: Nairobi, Kenya, 30 p.


Editor(s): Hinkel, K.M.
Collection: Proceedings of the Tenth International Permafrost Conference: Resources and Risks of Permafrost Areas in a Changing World

Editor(s): Tong, V.

Editor(s): I. Krupnik, I. Allison, R. Bell, P. Cutler, D. Hik, L.M. Jeronimo, V. Rachold, E. Sarukhanian and C. Summerhayes
http://w

Editor(s): Kaiser, B.

Editor(s): Kaiser, B.

Web/Internet Site

URL(s):
http://www.lter.uaf.edu/

Description:
This is the home page for the BNZ LTER site and is the portal through which all the data and other information from are site are available.

Other Specific Products

Product Type:
Data or databases

Product Description:
The Bonanza Creek LTER provides an on-line data catalog which currently contains 381 formally documented data sets; located at http://www.lter.uaf.edu/data_b.cfm. This collection contains physical, biological, modeling, and spatial data produced as a result of research at the BNZ LTER.

The following 111 datasets are currently ongoing and are being regularly updated.
1) Active layer depths: Bonanza Creek Fireline (1984 - Present)
2) Active layer depths: Boundary Fire Fireline (2004 - Present)
3) Active layer depths: Survey Line Fire (2004 - Present)
4) Active layer depths: Wickersham Fireline Sites (1972 - Present)
5) Air Temperature and Relative Humidity at Long Term Tree Growth Sites; 1989-Present: Hourly
6) Air Temperature and Relative Humidity at Long Term Tree Growth Sites; 2001-Present: Hourly
7) Air Temperature, Soil Temperature, Precipitation, Snow Depth at Long Term Tree Growth Sites; 1968-Present : Weekly
8)Alaska Tree Ring Data
9)Alaskan Peatland Experiment (APEX): Static chamber methane fluxes from bog sites, 2008-2011
10)Alaskan Peatland Experiment (APEX): Static chamber methane fluxes from fen sites, 2005-2011
11)Alder Canker Survey Initiated 2005
12)APEX beta NW site: hourly soil temperature, soil moisture, air temperature and RH, photosynthetically active radiation (PAR), and rain.
13)APEX beta SE site: hourly soil temperature, soil moisture and net radiation.
14)APEX beta SW site: hourly soil temperature, and soil moisture.
15)APEX fen control plot soil temperatures, 2005-Present
16)APEX fen Lowered plot soil temperatures, 2005-Present
17)APEX fen meteorological measurements
18)APEX fen Raised plot soil temperatures, 2005-Present
19)APEX gamma black spruce site: hourly soil temperature, soil moisture, air temperature and RH and photosynthetically active radiation (PAR).
20)Average Tree Growth (DBH,Circumference,and Basal Area) at LTTG Sites, 1969-Present: Yearly
21)Bonanza Creek Experimental Forest Beetle Population Counts
22)Bonanza Creek Experimental Forest Defoliating Insect Population Levels Per Leaf Beginning in 1975
23)Bonanza Creek Experimental Forest Defoliating Insect Population Levels Per Trap Beginning in 1975
24)Bonanza Creek Experimental Forest: Active layer depths at core floodplain sites
25)Bonanza Creek Experimental Forest: Barometric Pressure at LTER1, 1995 - Present
26)Bonanza Creek Experimental Forest: Dew Point measurements: hourly (1988 - Present)
27)Bonanza Creek Experimental Forest: Evaporation measurements from core sites: hourly (1988 - Present)
28)Bonanza Creek Experimental Forest: Hourly Relative Humidity (mean, min, max) at 50 cm and 150 cm from 1988 to Present
29)Bonanza Creek Experimental Forest: Hourly Precipitation data, 1988 to Present
30)Bonanza Creek Experimental Forest: Hourly Snow depth data, 1988 to Present
31)Bonanza Creek Experimental Forest: Hourly Soil Moisture at varying depths from 1988 to Present
32)Bonanza Creek Experimental Forest: Hourly Soil Temperature at varying depths from 1988 to Present
33) Bonanza Creek Experimental Forest: Hourly Temperature (sample, min, max) at 50 cm and 150 cm from 1988 to Present
34) Bonanza Creek Experimental Forest: Hourly Wind Speed and Wind Direction at 3 m and 10 m from 1988 to Present
35) Bonanza Creek Experimental Forest: Photosynthetically active radiation (PAR), 1988 - Present
36) Bonanza Creek Experimental Forest: Precipitation Weighing Bucket Measurements: hourly (1988 - Present)
37) Bonanza Creek Experimental Forest: PYR measurements: hourly (1988 - Present)
38) Bonanza Creek Experimental Forest: Snow Pillow measurements: hourly (1988 - Present)
39) Bonanza Creek Experimental Forest: UV measurements: hourly (1988 - Present)
40) Bonanza Creek Experimental Forest: Vapor Pressure measurements: hourly (1988 - Present)
41) Bonanza Creek LTER Photo Monitoring
42) Bonanza Creek moisture gradient physical data at BZBS: hourly temperature, moisture and photosynthetically active radiation.
43) Bonanza Creek moisture gradient physical data at BZDE: hourly temperature, moisture and photosynthetically active radiation.
44) Bonanza Creek moisture gradient physical data at BZEC: hourly temperature, moisture and photosynthetically active radiation.
45) Bonanza Creek moisture gradient physical data at BZTG: hourly temperature, moisture and photosynthetically active radiation.
46) Bonanza Creek moisture gradient physical data at BZWB: hourly temperature, moisture and photosynthetically active radiation.
47) Caribou-Poker Creeks Research Watershed Hourly Relative Humidity (mean, min, max) at varying heights from 1988 to Present
48) Caribou-Poker Creeks Research Watershed Radiation Measurements: Net Radiation, Up and Down Shortwave/Longwave Radiation
49) Caribou-Poker Creeks Research Watershed: Barometric Pressure, 2000 - Present
50) Caribou-Poker Creeks Research Watershed: Daily Flow Rates for C2, C3, C4
51) Caribou-Poker Creeks Research Watershed: Dew Point Measurements: Hourly Data
52) Caribou-Poker Creeks Research Watershed: Hourly Air Temperature (mean, min, max) from 1995 to Present
53) Caribou-Poker Creeks Research Watershed: Hourly Precipitation data, 1998 to Present
54) Caribou-Poker Creeks Research Watershed: Hourly Snow Depth Measurements
55) Caribou-Poker Creeks Research Watershed: Hourly Snow Pillow Measurements
56) Caribou-Poker Creeks Research Watershed: Hourly Soil Moisture at varying depths
57) Caribou-Poker Creeks Research Watershed: Hourly Soil Temperature at varying depths from 1988 to Present
58) Caribou-Poker Creeks Research Watershed: Hourly Wind Speed and Direction from 1988 to Present
59) Caribou-Poker Creeks Research Watershed: Vapor Pressure Measurements: Hourly Data
60) Chugach National Forest Beetle Population Counts
61) Cooperative Alaska Forest Inventory
62) Densities of snowshoe hares at Bonanza Creek Experimental Forest
63) Fireline surface level and thaw depths: Wickersham fire sites (1977 - 2009)
64) Greenup values for interior alaska 1976 - Present
65) Ground Water Depth Readings at BCEF/LTER Floodplain Sites, 1991-Present: Hourly
66) Ground Water Depth Readings at BCEF/LTER Floodplain Sites, 1991-Present: Weekly
67) Hectares of Alaskan Forested Ecosystems Infested by Phytophagous and Phloeophagus Insects, 1955-2008
68) Height and DBH measurements of Lodgepole Pine Plantations in Alaska: 1984 - 2004
69) Litter Trap Results at the Tanana River Exclosures: 2001 - Present
70) Litterfall and Hare Pellet Summary at Bonanza Creek LTER Control Plots (1985 - Present)
71) Litterfall collected from LTTG Sites (1 meter litter trays): 1967 - Present
72) Litterfall Weights From LTER Study Site Treatment Plots: 1990 - Present
73) Log Decomposition Dynamics in Interior Alaska 1 - Site Data
74) Log Decomposition Dynamics in Interior Alaska 2a - Log Data
75) Log Decomposition Dynamics in Interior Alaska 2b - Log Sampling Schedule
76) Log Decomposition Dynamics in Interior Alaska 3 - Disk Data
77) Log Decomposition Dynamics in Interior Alaska 4 - Nutrient Data
78) Log Decomposition Dynamics in Interior Alaska 5a - Preliminary Results (treatment down) - Absolute
79) Log Decomposition Dynamics in Interior Alaska 5b - Preliminary Results (treatment down) - Retained
80) Long Term Tree Growth Sites: Hourly Temperature and Hourly Relative Humidity at 150 cm from 1988 to Present
81) LTER treatment plot circumference growth: 1989 - Present
82) National Atmospheric Deposition Program (NADP): Concentration Data, 1992 - Present
83) National Atmospheric Deposition Program (NADP): Seasonal Wet Depositions Totals (kg/ha), 1992 - Present
84) NRCS Snow Survey Data
85) Photosynthetically active radiation (PAR) data from APEX Fen, 2005 - 2006
86) Rain, well and river water oxygen and deuterium isotope analyses/values for Bonanza Creek Experimental Forest and LTTG sites (2002 - Present)
87) Snowshoe hare pellet count data in Bonanza Creek Experimental Forest
89) Snowshoe hare physical data in Bonanza Creek Experimental Forest: 1999-Present
90) Soil Moisture (TDR) Measurements at LTER Moisture Exclusion Treatment Plots: 1994-Present (weekly)
91) Soil Moisture (TDR), Temperature, and Precipitation Measurements at FP3A Moisture Exclusion Treatment Plots: 2002-Present
92) Soil Moisture (VWC) at LTER Moisture Manipulation Treatments
93) Soil Temperature at LTER Moisture Manipulation Treatments
94) Soil Temperature measurements at Long Term Tree Growth Sites; 1989-Present: Hourly
95) Soil Temperature Measurements at LTER Floodplain Successional Sites (FP1A, FP2A, FP4A): 1985-present (hourly)
96) Spruce Seedling Data Bonanza Creek Experimental Forest Floodplain Inside and Outside of the Moose Exclosures
97) Stream water chemistry of CPCRW, 2002-2007
98) Summer Throughfall Precipitation Recorded at LTER Moisture Exclusion Treatment Plots: 1991-Present (weekly)
99) Sun Photometer - NASA Aerosol Robotic Network
100) The impact of permafrost thaw on ecosystem carbon balance: Carbon fluxes in a tussock tundra under permafrost thaw.
102) The impact of permafrost thaw on ecosystem carbon balance: net ecosystem exchange of a heterogenous landscape undergoing permafrost thaw
104) Tree band growth data taken at BCEF sites (1989-Present)
105) Tree Growth data taken at LTTG sites, 1969-Present: Reported Yearly
106) Tree inventory data taken at BCEF sites (1989-Present)
107) Tree stand structure summary at Bonanza Creek Experimental Forest LTER sites
108) Vegetation Plots of the Bonanza Creek LTER Control Plots: Species Count (1975 - 2004)
109) Vegetation Plots of the Bonanza Creek LTER Control Plots: Species Percent Cover (1975 - 2009)
110) Water table level data from APEX Fen plots, 2005-2006
111) Yearly Seedfall Summary at Bonanza Creek LTER Control Plots (1958 - Present)

Of the 268 competed datasets currently residing in the data catalog, the following 20 records have been released in the 2011 time period.

1) Alaska Lightning Strikes 1986-2010
2) Alaskan Peatland Experiment: Community structure and productivity data for 2007-2010 I - Species List
3) Alaskan Peatland Experiment: Community structure and productivity data for 2007-2010 II - Species Abundance
4) Alaskan Peatland Experiment: Community structure and productivity data for 2007-2010 III - Understory Biomass
5) Alaskan Peatland Experiment: Community structure and productivity data for 2007-2010 IV - Understory Vascular ANPP
6) Alaskan Peatland Experiment: Community structure and productivity data for 2007-2010 IX - Stem Density
7) Alaskan Peatland Experiment: Community structure and productivity data for 2007-2010 V - Moss NPP
8) Alaskan Peatland Experiment: Community structure and productivity data for 2007-2010 VI - Tree Biomass and NPP
9) Alaskan Peatland Experiment: Community structure and productivity data for 2007-2010 VII - BGNPP
10) Alaskan Peatland Experiment: Community structure and productivity data for 2007-2010 VIII - VGA
11) Alaskan Peatland Experiment: Community structure and productivity data for 2007-2010 X - Leaf Area
12) Chemistry of water sources to catchments of the BNZ and ARC LTER sites, 2009-2010
13) Environmental Attributes within Seven Alaska Caribou Herds Calving and Annual Ranges
14) Hess Creek: soil temperatures at different depths from 2007-2009
15) Impacts of wildfire on stream water chemistry
16) Soil N pools and process rates for catenas at Caribou-Poker Research Watersheds and the Kuparuk River
17) Statewide 2-km raster of number of fires within each 2-km pixel since 1942
18) Statewide 2-km raster of year since last wildfire
19) Stream chemistry along a latitude gradient, 2009
20) Surface and hyporheic water chemistry of the Tanana River

Sharing Information:
All datasets are publicly available on the Bonanza Creek LTER website.

Contributions within Discipline:
Please see Contributions within Discipline appended to the bottom of the Findings section.

Contributions to Other Disciplines:
Research at the Bonanza Creek LTER has contributed substantially to disciplines other than ecology, particularly to soil science, hydrology, and climatology. Upland and floodplain forests that we studied in the BNZ LTER develop in fundamentally different geochemical environments. The acidic upland soils are low in nitrogen due to N depletion by repeated fires. In contrast, the floodplain soils, which form from glacial silt, are strongly alkaline, due to surface evaporation (Marion et al. 1993). These soils bind phosphorus and are inherently low in nitrogen, leading to strongly nutrient-limited plant growth in the early stages of succession. Disturbance regimes differ radically between upland and floodplain ecosystems, with upland landscape pattern controlled largely by fire (Kasischke et al. 1995a) and floodplains responding to fluvial processes (Yarie et al. 1998, Adams 1999). Microclimate in the boreal forest differs dramatically between north-and south-aspect slopes, due to large differences in solar radiation and soil temperature, allowing us to study the impact of climate on ecosystem processes under conditions where other state factors are held relatively constant (Jenny 1941). Permafrost, which is generally present on north-facing slopes and valley bottoms (but absent on south-facing slopes) dramatically reduces rates of biogeochemical cycling, nutrient supply, and forest productivity (Van Cleve et al. 1983, Van Cleve et al. 1991). We now know that in contrast to the continuous permafrost zone of the Arctic, changes in the discontinuous permafrost zone of the boreal forest are driven primarily by changes in ecosystems rather than by climatic change (Jorgenson et al. 2010). In Interior Alaska, for example, changes in air temperature have had less effect on permafrost temperature than do changes in the insulative properties of snow, vegetation, and the surface organic layer. Permafrost temperatures were relatively stable from the 1950s to the mid-1970s, but have increased in response to the recent warming (Osterkamp and Romanovsky 1999). In ice-rich sites, melting of permafrost has caused widespread thermokarst (slumping of the ground surface) (Osterkamp et al. 1994), causing large changes in soil moisture and temperature.

Following a gradual cooling over the last 1,000 years, the Alaskan climate has warmed since about 1850, and more dramatically since the mid-1970s, due to changes in atmospheric circulation, perhaps superimposed on greenhouse warming, (Hammond and Yarie 1996, Mantha et al. 1997, Overpeck et al. 1997, Serreze et al. 2000). Tree-ring analysis shows that this warming is unprecedented in the past 200 years (Juday et al. 1998). The average annual area burned has doubled in boreal North America in the last ten years, in parallel with the warming trend (Kasischke et al. 1999). Lake cores suggest that the fire return time in the 20th century is only half as long as the average for the last 1000 years. The increase in early successional deciduous vegetation caused by fire increases regional albedo and evapotranspiration and reduces sensible heat transfer to the atmosphere. This acts as a negative feedback to regional warming (Chapin et al. 2000).

In summary, changes in the Earth's Climate System have led to pronounced warming in the Alaskan boreal forest, causing melting of permafrost, increased fire frequency, and fire-induced vegetation changes that may cause a negative feedback to regional warming. As discussed below, forest dynamics and biogeochemical cycling play a critical role in this interaction between the boreal forest and climate.

Contributions to Human Resource Development:
Please see our section on Training, Development, and Mentoring in Activities and Findings for detailed information on our contributions to human resource development.

Contributions to Resources for Research and Education:
Direct contributions to education are described in the previous section. In addition to those direct contributions, the BCEF and the Caribou-Poker Creeks Watershed Research Area provide a widely-used educational resource for the community. Both have been used by educators and their students in college level courses for biology and non-biology majors. This includes field courses taught in Alaska by educators from UAF and other universities, such as the Arctic Ecology field course taught at the Toolik Lake Field Station. Each year, BNZ scientists spend several days teaching boreal forest ecology to this course in Fairbanks. Bonanza LTER scientists have collaborated with and contributed to the growth of other science education programs, i.e. expansion beyond the Fairbanks, Alaska school system. See the sections on Training, Development, and Mentoring and Outreach Activities for more details. Bonanza LTER scientists are collaborating closely with management agencies, particularly those involved with fire, wildlife, insect and pathogen outbreaks, forestry, and subsistence resources to inform them of the management implications of Bonanza LTER research. Our accessible online data base is an additional resource available for use by researchers and educators within and beyond BNZ. The sites and their management are briefly described below.

Site Management

Leadership structure

NSF and the USDA Forest Service, through the Pacific Northwest Research Station, jointly fund the BNZ LTER project. Direct financial support from the USFS constitutes approximately 16% of total project costs. However, support from USFS for FY11, FY12, and FY13 has been cut substantially, and there is considerable uncertainty about the sustainability of USFS funding for the BNZ LTER. Ruess and Hollingsworth visited with Bov Eav (Director, USFS PNW) last April 2012 and were pleased to learn of his continued commitment to the BNZ LTER. However, the USFS is facing significant budget cuts, and Bov is retiring at the end of 2012 ? so we remain concerned. USFS funds to the BNZ LTER support a large proportion of our monitoring program, and the salaries of Hanley and Hollingsworth. We view NSF and USFS components of the LTER program as being thoroughly integrated into a single program, so we describe the management as it actually
functions, rather than distinguishing between the NSF and USFS components.

Our leadership team consists of the PI (Ruess) and co-PIs: Hollingsworth, Jones, Mack, and McGuire. Hollingsworth is a Research Scientist at the USFS Boreal Ecology Cooperative Research Unit (http://www.becru.uaf.edu/). Hollingsworth is closely involved with the BNZ science plan, trains graduate students, and is now the chief scientist on our Joint Venture Agreement with the USFS (replacing Hanley, who is soon to retire). Scientific decisions in the BNZ LTER are made at several levels:

1. Ruess serves as the PI of the LTER research program and is ultimately responsible to NSF for the overall design and implementation of the research program. However, he works collaboratively with Co-PIs (Hollingsworth, Jones, Mack, and McGuire), and other Senior Investigators on the coordination and implementation of the program.

2. In practice, the five-person leadership team makes decisions jointly about the design and implementation of the research program. Each of us has responsibility for overseeing specific aspects of the program: Ruess, overall integration (within-site and with network) and site management; Hollingsworth, Forest Service communication; Jones, permafrost/hydrology, Mack, vegetation/fire disturbance; McGuire, data management and modeling.

3. The LTER executive committee (leadership team plus Yarie, site manager (J. Hollingsworth), data manager (J. Downing), and student representative (R. Hewitt)) provides feedback concerning major issues associated with program direction (e.g., conceptual framework and general design of this proposal), and is responsible for the day-to-day logistics of the program. In practice, these meetings are open to all LTER personnel, and there is broad participation by the LTER community.

4. Two or three individuals are responsible for coordination and integration within each research theme: Direct effects of climate change on ecosystems and disturbance regimes (Hollingsworth, Johnstone, Mack); Climate-disturbance interactions as drivers of ecosystem and landscape change (Mack, Jones, Ruess); Regional Ecosystem Dynamics and Climate Feedbacks (McGuire, Euskirchen); Coupled social-ecological dynamics of interior Alaska (Kofinas, Kielland, Rupp).

5. There are 1-2 leaders plus a planning team responsible for designing and implementing each research task and for making sure that the research addresses hypotheses and questions of the research themes and the overall project goals.

6. Each investigator is allocated a budget and is responsible for designing and implementing her/his portion of the research program.

Program integration and communication

Our executive group meets approximately monthly to address practical issues and to plan and coordinate our within-site synthesis activities. All senior investigators and graduate students attend our research symposium, held annually in Fairbanks, to conduct synthesis of our major themes. This annual symposium is also attended several invited scientists from state and federal agencies within Alaska, and defines topics for a series of monthly webinars held throughout the following year. A final level of communication and integration is facilitated by the coordination of field logistics and activities during both winter and summer.

Site security and site management

The BNZ research program has two intensive research areas: The Bonanza Creek Experimental Forest (BCEF) is located within the Tanana Valley State Forest and is leased to the USFS (renewable in 2018). The Caribou-Poker Creek Research Watersheds (CPCRW) includes lands under the jurisdiction of the University of Alaska and the Alaska Department of Natural Resources. The LTER manages BCEF and CPCRW for the purpose of conducting research. We have close working relationship with Alaska Department of Natural Resources, Division of Forestry and Division of Lands, Mining and Water to protect the long term availability of these areas for research. The BNZ site manager (Jamie Hollingsworth) is responsible for managing LTER research in the two research sites, including permitting, transportation, and the planning and implementation of the core research program. Significant improvements in site management in the last funding cycle include expanding our sensor network with radio communications for our 10 plus microclimate stations, improved coordination of field work, improved boat communication and safety, and assessment of statistical power and required sample sizes for long-term vegetation measurements. These efforts have substantially improved the quality, continuity, efficiency, and safety of data collection, releasing time to undertake new activities. As mentioned above, we have expanded our monitoring program to include a new regional network of black spruce sites that more closely match our evolving focus on ecosystem resilience and mechanisms of landscape change. This new network includes 108 extensive sites and 36 intensive monitoring sites positioned within the 3 interior Alaska ecoregions on land owned primarily by the State of Alaska, Bureau of Land Management, and Native corporations.

The CPCRW is the candidate core site for the taiga domain of NEON, which will provide the infrastructure to measure larger scale measurement of CO2, CH4 and water vapor fluxes, and energy exchanges. Additionally, relocatable towers for the taiga domain will be
installed in a recently burned area near CPCRW and at our Eight Mile Lake watershed site to examine the effects of wildfire and permafrost thaw on ecosystem C and energy exchanges. CPCRW will also host a NEON aquatic array and a STREON site, which will provide the infrastructure to examine stream hydrology, and DOC and nutrient fluxes at a higher temporal resolution than is currently possible, and will allow expansion of our watershed solute export studies to higher-order streams.

Engagement of new investigators, non-LTER scientists, and the Fairbanks community

We added 3 new investigators in the most recent proposal, and have adjusted individual budgets to meet the needs of our focus on mechanisms of resilience, climate feedbacks and human dimensions. New investigators include Eugenie Euskirchen (modeling) and Diane Wagner (insect population dynamics). Mary Beth Leigh (IAB faculty member and professional dancer) recently joined the BNZ LTER as our liaison to the Fairbanks arts community, and has organized several community events bringing together ecologists and local artists (http://www.lter.uaf.edu/outreach/bnz_Collaboration.cfm). This past year, Tamara Harms, an ecohydrologist working at CPCRW and near the ARC LTER, became a new IAB faculty member and we expect her formal involvement with the BNZ LTER to increase. We have been modestly successful in increasing diversity among PIs and senior investigators at our site, going from one woman and no minorities 10 years ago to 12 women (42%) and two minorities in our current proposal. Of the 85 LTER-affiliated graduate students in our last grant period, 11% are minorities (Native American, Asian, and Hispanic/Latino) and 56% are women. Our major effort to enhance diversity is through recruitment of minority graduate students, particularly Alaska Natives. Minority recruitment has been a strong emphasis of the IGERT program in Resilience and Adaptation (see Outreach), and many of these students become involved in BNZ LTER research. A key way in which we engage non-LTER investigators in our LTER research is through our affiliate LTER investigator program. The BNZ LTER affiliates are encouraged to participate in our annual symposium, have the same access to LTER data, field sites, and facilities as do LTER Senior Researchers, and are encouraged to archive their data in the LTER database. Terry Chapin has officially retired from UAF and moved into the role of Affiliate LTER investigator, although he maintains close ties to the BNZ through his active research program. We attempt to provide transportation costs to the LTER symposium and assist with field logistics whenever possible. Many affiliates have written proposals with LTER investigators as a result of this collaboration. A full list of outside funding sources is appended at the bottom of the Activities section.

Data and information management

Overview of Site Activities:

The primary goal of data and information management at the Bonanza Creek LTER is to ensure the long-term archiving of the program's datasets as well as to explore new techniques in data storage, sharing, and management. Of primary concerns are metadata, quality control, accessibility, timely entry of data, and the security of datasets. Additionally, we work to employ emerging technologies and data management techniques in order to provide a system that engenders trust, collaboration and efficient information exchange.

The current BNZ data management architecture is established on a series of computers. The primary server is a Dell Power Edge 2950 server running Red Hat Enterprise Linux AS release 5.2 (Tikanga) which is used as the primary web and file storage server in addition to hosting the MySQL 5.0.22 database managing our datasets, site, and personnel information in a client-server relational database environment. Another Dell Power Edge 320computer running Windows Server 2012 and ESRI GIS Serve Software is used as the GIS Information Server. This internet map server displays spatial information about our datasets, projects, study sites, administrative boundaries, and ecological characteristics of interior Alaska. Another Dell Power Edge 310 computer running Windows Server 2008R2 that hosts software for the acquisition and management of our sensor network data. The sensor network server uses LoggerNet (Campbell Scientific) to provide field data logger management and download operations while another software package, Vista Data Vision (Vista Engineering), functions in conjunction with the LoggerNet software to provide a real-time graphical web interface to view, download and easily manage the streaming sensor data that resides in a MySQL relational database on the back end. These primary servers, and key workstations, are backed up on external hard drives, as well as on backup systems in cooperation with the UAF Scenarios Network for Alaska & Arctic Planning (SNAP) and the UAF Arctic Region Supercomputing Center (ARSC).

We utilize a robust client-server relational database system as the primary means of data search and retrieval. This system simplifies back-up procedures while the database tracks changes in data and metadata and allows data sets to be viewed using web scripts, allowing users to query, view and download metadata and data. These features provide a more interactive and productive web experience when searching for specific datasets or datasets associated with an individual investigator's research. We have also created an internet-based data submission system that interacts with our database for submission and tracking of metadata and data files into our system. In addition, the BNZ LTER has EML compliant metadata metadata files for each of our 419 datasets, which is generated with a Perl script and a XSLT style sheet transformation customized to produce highly enriched metadata content.

The BNZ data catalog currently contains 419 distinct data packages. Of that, 143 of these data packages are ongoing and being routinely updated. During the last year we have added 38 new completed data packages from investigators, research associates, or students and we
Datasets in the BNZ LTER databank are made available to other researchers in as timely a manner as possible. The primary means of metadata and data dissemination is through the internet. Commonly used datasets, and climate data in particular, are usually made available via our website within a month after its collection, and several of our major weather stations provide web-accessible data in real time. Other core datasets are generally made available as soon as annual field work is terminated and the data entered. The LTER executive committee and support staff encourage investigators to submit new project data within the time mandates required, usually two years. In general, datasets are made publicly available as soon as they are archived, but some datasets may require delayed or restricted access, particularly data from graduate student projects. In such cases the student is preparing for graduation and may not have had a chance to publish their data, but we need to engage them in data archiving before they graduate, while their interest is high. Such datasets must be archived but may be withheld from the public for a period of time to allow the student to fully exploit their data before it is made public. We have not yet had a graduate student request to withhold data from the web.

We also implement programmatic systems that allow for harvests of our data by the LTER Network Office and ClimDB. HydroDB is also updated yearly for the previous water years' data as soon as the year end analysis is complete. We participated in the Veg-DB workshop at Harvard Forest last summer, have been instrumental in the Network-wide cryosphere group, and will be participating in the network biogeochemistry synthesis workshop this spring. The publications database and archive information is also provided to the LTER Network office and the U.S. Forest Service, PNW Research Station.

The worldwide web is an efficient means of serving information about our program. Server logs indicate that our primary web site receives nearly 9,000 unique visitors and about 280,000 individual hits each month. While the majority of use comes from US Educational, Network and Commercial sites, notable usage is seen from the Russian Federation, the US Government, and Canada. We see usage from numerous other countries and non-profit organizations as well. The most popular modules include our internet map server, data catalog, bibliography, and personnel information. Much of our meteorological data are available in real time, facilitated by a radio network and internet connection linking field data loggers to the relational database. We have additionally begun to implement Google Analytics software within our website to even better track our web systems usage and guide development.

Network Data Management Activities:
* IMEXEC (http://im.lternet.edu/home/imexec): The BNZ Information Manager, Jason Downing, continues to serve an elected seat on the Information Managers’ executive committee (IMEXEC). Participation on this committee involves monthly meetings to coordinate activities of the IMC group and liaison with the LNO, EB, NISAC, and NSF. Jason attended his first annual meeting for the group in Feb 2012 which included meetings with Saran Twombly, which has led to an expanded dialogue between information managers and NSF personnel.
* IMC Working Groups (http://im.lternet.edu/projects): Over the last year, BNZ personnel have participated in several standing information management working groups. Jason Downing participated in activities by the Vocabulary WG, the Unit Dictionary WG, the Web Services WG, SiteDB WG and the EML Quality WG while Jamie Hollingsworth continued to be a play an integral role with the GIS WG.
* ASM Working Groups
GIS Data and Tools for the LTER: resources for site research and synthesis: This workshop provided presentations on GIS data and tools available for the LTER, discussions of options for data access at specific LTER Sites, as well as introductions to plans for future development. There was also discussion about how to implement these technologies at LTER sites, and how GIS and Remote Sensing data fit within the Network Information System (NIS).
SensorNIS: Building a sensor network resource guide through community participation: LTER sites are actively deploying, operating, or exploring establishment of sensor networks and are commonly in need of informational resources as these networks are being developed. Jason Downing co-sponsored this ASM working group charged with developing an online knowledgebase focused on the design, implementation and long-term management of electronic sensor networks
* ASM Poster: Tools for assessing EML data package quality: Since 2009, the LTER Information Managers Committee (IMC) has been developing a system of quality standards for EML data packages to assure that PASTA-components of the LTER Network Information System (NIS) are of high quality. Jason Downing assisted in producing this poster to outline and discuss the recent activities and accomplishments of this working group.
* LTER NIS Sponsored Training Sessions
LTER Training: Tools and training for sensor network establishment and management: Jason Downing received funding and attended this LTER-sponsored training session at the LTER Network Office teaching lab in ABQ: May 1-4, 2012. The goal was to promote best practices for sensor management and provide hands-on training in the use of existing tools and common software. This workshop was designed to introduce several options for managing streaming sensor data, discuss requirements for sensor data management systems and best practices in quality assurance and quality control (QA/QC).
these types of issues could contribute significantly to Network-wide efforts towards rule-based social-ecological modeling.

Dangerous Ice, which is addressing perceived consequences of changing winter ice on rural subsistence communities. We would imagine that including wolves, fox, beaver, mink, and lynx. Knut Kielland has been involved with a Coupled Human and Natural Systems proposal, burbot, whitefish, and northern pike), river floodplains are hunted for moose and waterfowl, and trapped for a number of fur-bearing species, ice-fishermen, and are affected by the timing of river freeze, ice conditions and breakup. In addition to providing harvestable fish (salmon, among many interior villages. Moreover, ice-covered rivers are also used extensively by recreational skiers, dog mushers, snow-machiners, and remain dependent on barge shipments of fuel and nearly all other non-subsistence supplies. During winter, rivers are the major travel corridor activities account for historical and current human settlement along interior Alaskan floodplains. The economies of many rural Alaskan villages significantly influence ways in which humans access and use these landscapes. Uses of rivers for transportation, commercial and subsistence management agency personnel to identify key components for integrating ecological, social, economic, and policy components into a working research framework. Climate sensitivity of river discharge and flooding are important issues to Alaskans since fluvial processes of large river systems within interior Alaska drive landscape evolution, vegetation succession and trophic dynamics in floodplain ecosystems, and

Contributions Beyond Science and Engineering:
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Bonanza Creek repeatedly made invited contributions to the LTER symposium intended for NSF and other agency representatives and to the annual LTER Network Science Meeting. Bonanza Creek continues to contribute actively to network planning for Integrative Science for Society and the Environment (ISSE): (1) as a framework for interdisciplinary research integrating natural and social sciences both within Bonanza Creek, and across sites (e.g. the Maps and Locals (MALS) project, which is coordinated by Gary Kofinas from BNZ) and (2) as a basis for inter-site comparisons with other LTER sites that address changes in disturbance regimes (particularly fire, insect/pathogen outbreaks, permafrost, flood dynamics) as an important force determining the structure and functioning of their site.

We believe the BNZ LTER is well poised to make significant contributions to the intersite research plan addressing 1) Urbanization, exurbanization, and working systems, 2) Ecological and social responses to climate change and variability, and 3) Biotic, water and nutrient changes in social-ecological systems. One of the recent supplements to the BNZ LTER, The moose-human social ecological system of interior Alaska, addressed each of these Network research themes. For example, we are interested in documentation of rural and urban residents' perceptions of changes in ecosystem services and human responses to those changes. We are also interacting with rural residents and management agency personnel to identify key components for integrating ecological, social, economic, and policy components into a working research framework. Climate sensitivity of river discharge and flooding are important issues to Alaskans since fluvial processes of large river systems within interior Alaska drive landscape evolution, vegetation succession and trophic dynamics in floodplain ecosystems, and significantly influence ways in which humans access and use these landscapes. Uses of rivers for transportation, commercial and subsistence activities account for historical and current human settlement along interior Alaskan floodplains. The economies of many rural Alaskan villages remain dependent on barge shipments of fuel and nearly all other non-subsistence supplies. During winter, rivers are the major travel corridor among many interior villages. Moreover, ice-covered rivers are also used extensively by recreational skiers, dog mushers, snow-machiners, and ice-fishermen, and are affected by the timing of river freeze, ice conditions and breakup. In addition to providing harvestable fish (salmon, burbot, whitefish, and northern pike), river floodplains are hunted for moose and waterfowl, and trapped for a number of fur-bearing species, including wolves, fox, beaver, mink, and lynx. Knut Kieland has been involved with a Coupled Human and Natural Systems proposal, Dangerous Ice, which is addressing perceived consequences of changing winter ice on rural subsistence communities. We would imagine that these types of issues could contribute significantly to Network-wide efforts towards rule-based social-ecological modeling.
Another contribution of the BNZ LTER is towards network-wide efforts to synthesize an understanding of loss of the cryosphere. Changes in permafrost throughout interior Alaska have profound consequences for ecosystem structure and function. Thermokarst, for example, may initially lead to an expansion of small lakes and ponds, and over the long term lead to a drying of the surface. Changes in ecosystem services associated with warming permafrost have implications for both urban and rural residents of interior Alaska. Rural residents will be disproportionately affected by changes in subsistence resource use associated with changes in ease of access to the landscape as well as direct effects associated with changes in the quality of habitat for wildlife subsistence species, such as moose. Urban residents will be affected by changes in the cost and ease of road-building and construction as permafrost warms and thaws. Human decisions, on an individual and policy level, may in turn feedback to have a large effect on the dynamics of permafrost thaw. For example, regulations that affect development (buildings and roads), mining, and resource use will all directly influence the dynamics of permafrost thaw. Finally, the BNZ LTER has a number of research efforts studying trophic structure, biodiversity and invasive species, and are working closely with personnel from state and federal agencies within Alaska focusing on these topics. In many ways, we represent the endpoint along a number of continuums across the Network. These include low vascular plant diversity but high non-vascular and microbial diversity, low numbers of invasive species but extremely rapid rates of introduction, extreme top-down control of ecosystem function by vertebrate mammals and high dependency on subsistence food use by urban to rural residents, and extremely high cultural identity to a landscape that is undergoing rapid environmental change. Our early work on bringing all of these factors into a social-ecological context offers unique contributions to any intersite science plan.

**Conference Proceedings**

**Special Requirements**

Special reporting requirements: None
Change in Objectives or Scope: None
Animal, Human Subjects, Biohazards: None

**Categories for which nothing is reported:**

Any Conference
Contributions Within Discipline

1. Through long-term studies of fire cycles and their links to climate, BNZ scientists have documented an increase in fire severity brought on by climate warming that will likely shift the Alaskan boreal forest from a spruce- to a broadleaf-dominated landscape.

Plant ecologists working with the LTER program in Alaska have found that fire effects on soil organic layer depths is a key factor that can disrupt stable patterns of conifer dominance in the boreal forest. Plant-soil-microbial (PSM) feedbacks between vascular plants, mosses, and microbial decomposition maintain deep organic soils in black spruce forests and wetlands of Interior Alaska (Johnstone et al. 2010a). This internal feedback has been a key source of ecosystem resilience under the historical fire regime; moist, cold soils, poorly drained due to permafrost, burn at low severity and leave the surface organic layer largely intact. Thick organic layers burned at the surface create a seedbed that favors the re-establishment of black spruce and mosses. The system quickly returns to a structure similar to that of the conifer-dominated, pre-fire forest.

However, stabilizing feedbacks between plants and soil in the boreal forest can be disrupted by unusual fire events. In extreme fire years, severe fires can consume much of the soil organic layer. When less than ~5 cm depth of organic soil remains after fire, deciduous tree species such as aspen and birch can establish at high densities (Johnstone et al. 2010b). From long-term studies of forest succession at the Bonanza Creek LTER sites, we know that this period of initial post-fire succession sets the stage for decades to centuries of plant succession. Thus, the change in seedbed conditions caused by a severe fire can catalyze a switch from conifer dominance to alternate plant successional trajectories dominated by deciduous trees.

Once deciduous forests become established, a new domain of PSM feedbacks emerges where shallow organic soils are maintained by rapidly decomposing litter from highly productive deciduous species. Deciduous broadleaf trees increase rates of evapotranspiration and export moisture from the soil to the atmosphere. Once thick organic layers are consumed by fire, permafrost degradation is likely, leading to a state change that permanently alters ecosystem structure and function. Shifts between domains of spruce vs. deciduous dominance and the resulting effects on permafrost have large implications for ecosystem productivity and carbon storage, feedbacks to regional climate, the goods and services that boreal ecosystems provide to humans. Indeed, BNZ scientists have shown that shifts from conifer to deciduous forest cover can largely compensate for the carbon emissions caused by increasing wildfire (Randerson et al. 2006). This research demonstrates that stabilizing feedbacks within the dominant forest type can be disrupted by changes to climate and disturbance regimes, initiating rapid transformations of the forest landscape with regional to global consequences.


Figure 1: Large fires in the boreal forests of Alaska may stimulate transitions from black spruce (see the patch of unburned trees in the foreground) to a landscape matrix dominated by deciduous tree species. Photo taken near the Caribou Poker Creek Research Watershed of the Bonanza Creek LTER site.

Figure 2: Output from a boosted regression tree model showing the variables most important in predicting the proportional dominance of black spruce in post-fire regenerating stands. Fire severity, measured by the Composite Burn Index (CBI) shows the strongest effects in determining whether burned black spruce stands will recover to be dominated by spruce (low severity) or deciduous species (high severity). Stand age and site moisture also have important effects on the dominance of spruce in the post-fire regenerating forests. From: Johnstone, J. F., F. S. I. Chapin, T. N. Hollingsworth, M.
2. **BNZ scientists have discovered that the thaw of permafrost induced by climate change is causing the rapid decomposition of previously frozen organic carbon in boreal forest soils. This CO$_2$ release is likely to amplify climate warming to the same extent as land use change worldwide.**

At least 1218 Pg (billion tons) of soil carbon (C) are stored in surface permafrost soils in boreal and arctic ecosystems, almost twice as much C than currently contained in the atmosphere (Tarnocai et al. 2009). Latitudinal gradients of soil C storage, field experiments, and laboratory incubations all show that soil C cycling in these northern ecosystems is likely to be strongly influenced by the effect of cold temperature on rates of decomposition of soil organic matter. This ‘old’ soil C, climatically protected from microbial decomposition in frozen or waterlogged soil, has been accumulating in these ecosystems throughout the Holocene, and for much longer in some unglaciated areas.

The BNZ LTER report results from a tundra landscape undergoing permafrost thaw, where net ecosystem C exchange and the radiocarbon age of ecosystem respiration were measured to determine the influence of old C loss on ecosystem C balance (Schuur et al. 2009). Sustained transfers of C to the atmosphere that could cause a significant positive feedback to climate change must come from old C, which forms the bulk of the permafrost C pool that accumulated over thousands of years (Schuur et al. 2008). Areas that thawed over the past 15 years had 40% more annual losses of old C compared to minimally thawed areas, but had overall net ecosystem C uptake as increased plant growth offset these losses. In contrast, sites that thawed decades earlier lost even more old C, a 78% increase over minimally thawed areas, which contributed to overall net ecosystem C release despite increased plant growth. These data document significant losses of soil C with permafrost thaw that, over decadal time scales, overwhelms increased plant C uptake at rates that could make permafrost a large biospheric C source in a warmer world, similar in magnitude in the future to current C fluxes from land use change. At present, increasing greenhouse gases responsible for climate change are largely a result of human activities. However, climate change may alter the natural cycling of carbon in ecosystems far from direct human influence. This research is key for understanding how terrestrial system feedbacks will interact with human emissions, and may influence policy-driven emission mandates aimed at controlling the overall rate of climate change.


Figure 3: Photograph of typical thermokarst feature in the Noatak Valley, Alaska.

Figure 4: Old carbon loss and its relationship to total ecosystem respiration for three sites that differ in the extent of permafrost thaw. a) Growing-season loss of old C from deeper in the soil profile, based on statistical partitioning estimates of mean proportional old C loss multiplied by ecosystem respiration (Reco) flux measurements. Error bars represent the spatial variability of Reco fluxes. b) The relationship between total Reco and proportional old C loss for the growing season across sites. Error bars represent the interannual variability in C loss estimates; the regression line is shown for n=3 sites.
3. By tracking seasonal changes in snow cover for decades, BNZ scientists have discovered that the snow free season in the boreal forests of Alaska is lengthening and likely to speed the rate of warming by increasing the amount of light energy absorbed by the land surface.

Modeling simulations over boreal Alaska have documented changes in albedo due to changes in the duration of the snow season and due to changes in the amount of young forest stands on a landscape due to changes in the fire regime. In addition, changes in the exchange of the greenhouse gases CO₂ and methane have also been estimated due to changes in climate, atmospheric carbon dioxide concentrations, fire regimes, and methane emissions. The sum of these feedbacks indicates that changes in boreal Alaska acted to warm the atmosphere between 1970–2000 and between 2003–2100. The strongest feedback to climate warming was derived from a lengthening of the growing season (reducing the snow-albedo feedback) between 2003–2100, and this was only partially counterbalanced by the cooling effect of an increase in the amount of young stands in the landscape under more severe fire regimes, and increases in carbon uptake by terrestrial ecosystems between. Furthermore, under a warmer, wetter climate the amount of methane released from Alaska’s peatlands increased between 1970 – 2000 and between 2003 - 2100, acting as an additional positive feedback to climate warming.


Figure 5: Changes in the duration of the snow season represent a strong positive feedback to climate warming due to the contrast in surface reflectivity between snow-covered and snow-free ground.
4. **Nitrogen is an essential nutrient that plants need to live and grow.** BNZ scientists have discovered that boreal forest trees and other plants can acquire nitrogen from organic compounds known as amino acids rather than mainly from inorganic sources as is the case in almost all other ecosystems.

Biogeochemical investigations have a long history at BNZ. These studies have demonstrated how slowly soil organic matter turns over in boreal forest soils, because of low biological activity coupled to a very short growing season. Recently, however, we have learned that nitrogen cycling in boreal forest soils continues past freeze-up and that about 40% of the annual nitrogen flux occurs during winter. Whereas decomposition and nitrogen mineralization may appear slow compared to more temperate ecosystems, there are other avenues of soil N supply which support the demand of the vegetation across primary succession on the Tanana River floodplain. For example, the production and turnover of dissolved organic nitrogen in boreal forests appear to be as rapid as that of inorganic nitrogen, and the uptake of amino acids by plants and microbes appears equally important as the uptake of dissolved inorganic nitrogen (McFarland et al. 2010). Soils on the Tanana River floodplain exhibit both qualitative and quantitative shifts in biogeochemical processes across succession. Early successional soils which have low organic matter content are characterized by low in situ rates of nitrogen mineralization and proteolysis (Kielland et al. 2007). Nitrogen mineralization increases with increasing soil organic matter content, reaches a peak in mid-succession, and declines thereafter possibly due to an accumulation of recalcitrant soil organic matter derived from the dominant coniferous tree species. By contrast, soil proteolytic activity and the turnover of free amino acids increases steadily across succession despite marked reductions in soil temperatures (Kielland et al. 2007). This diversity of biogeochemical processes is reflected in qualitative changes of the nitrogen economy of successional vegetation. Thus, early successional, riparian species such as willows rely to a large extent on nitrogen in the form of nitrate supplied by sub-surface water flow. Mid-successional species absorb nitrate (from river water), and ammonium and amino acids derived from
soil. Late successional conifers appear to take up nitrogen in the form of amino acids and ammonium derived from soil organic matter turnover (Näsholm et al. 2009). The substantial range of biogeochemical processes controlling plant nitrogen supply, and the large variation in the forms of nitrogen taken up by boreal forest species suggests that these forests may be more resilient to disturbance, such as climate change, than has hitherto been posited.


Figure 7: Mid-successional balsam poplar trees rely on several mechanisms of nitrogen acquisition, including nitrate uptake from hyporheic water, ammonium from soil N mineralization, and direct uptake of free amino acids in the soil.

Figure 8: The production of free amino acids via proteolysis increases across succession from the warm, alkaline soils of deciduous shrub stands to the acidic, permafrost-dominated stands of black spruce. From: Kielland et al. 2007.
5. For more than 20 years, BNZ scientists have studied the hidden impact of browsing on ecosystems by conducting experiments that exclude moose and snowshoe hare from large areas. Results show that browsing controls which plant species dominate, how large some trees grow, and how rapidly nutrients cycle through the ecosystem.

Studies of the interactions between vegetation processes and mammalian herbivory have been part of BNZ LTER research for over 20 years. We have found that browsing by moose and snowshoe hares controls vegetation development and nutrient cycling at a variety of scales. Mammalian herbivores control species composition, nutrient cycling, and plant population dynamics at the stand and landscape levels, and these effects are manifested both in early and late succession via herbivore effects on the interaction of biotic and abiotic processes.

Primary succession on the Tanana River floodplain is initiated by plant establishment on newly formed silt bars formed by flooding. Whereas all the major plant species (willows, alder, balsam poplar, and spruce) are present in this early wave of colonizing, the successional trajectory is characterized by distinct vegetation stages reflecting the life history traits of these dominant species. Because of their high population densities in interior Alaska, mammalian herbivores may consume over 50% of the current annual growth. Consequently, they have major impacts not only on plant growth but also on nutrient cycling processes since litter from browsed plants tends to have higher nutrient concentrations and faster decomposition rates. Perhaps the largest effect of herbivory on nutrient cycling is the selective browsing by moose and snowshoe hares on willows, which leads indirectly to the dominance of alder, an important nitrogen-fixing species. During periods of high snowshoe hare density, browsing on seedlings of late-successional species such as white and black spruce can result in effects on forest community composition that persist for decades. Studies of snowshoe hare populations at BNZ have shown that, in addition to the classical decadal population cycle, hare abundance varies nearly as much on an intra-annual basis, underscoring the large oscillations of resource availability in boreal forests.

The effects of mammalian herbivory can also alter the activity and abundance of insects and other arthropods. For example, the longer shoots produced by browsed willows experience higher rates of sawfly infestations than the shorter shoots on mature-growth form plants. Moreover, the generally warmer and drier microclimate on the forest floor, caused by browsing-induced changes in canopy structure, results in altered composition in the guilds of ground-dwelling insects. Thus, mammalian herbivory exerts significant control over biogeochemistry and successional dynamics at the level of the species, community and the ecosystem.


Figure 9: Moose are commonly encountered by BNZ research personnel during winter. Despite high rates of predation by wolves and resident hunters, the moose population in the Tanana Flats is amongst the highest (~1 moose/km$^2$) in North America.

Figure 10: Changes in alder and willow abundance (expressed as leaf litter biomass ratio) in the presence and absence of mammalian herbivory on the Tanana River floodplain.

6. Understanding gained through long-term research at BNZ suggests that traditional knowledge and ways of life will be important means by which Alaskan indigenous communities will adapt to changes in climate and fire regimes.

Changes in climate and fire regime are already affecting rural Alaskan communities where indigenous people have historically led a subsistence lifestyle as hunters, fishers, and gatherers. Warming has changed the timing of freeze up and melting of rivers and reduced the thickness of river ice and therefore reduced the safety of winter travel and access to some hunting grounds. Increased evapotranspiration and lower river levels reduce opportunities for barge delivery of
fuel and increase the cost of living and therefore the dependence on subsistence harvesting. Now that communities are permanently situated rather than semi-nomadic, the increased wildfire risk caused by warmer drier conditions is substantially affecting rural communities. Wildfire is a risk to life and property, reduces access to the land, threatens cultural and historic resources, and reduces moose and caribou abundances for one to several decades. Sources of resilience to address these changes include local residents’ intimate knowledge of village homelands, oral traditions transmitted by community elders and traditional sharing networks that maintain community identity while sustaining food supplies to the most vulnerable households and allowing hunters to borrow hunting equipment. As the abundance and distribution of subsistence resources change and access to hunting areas is modified, hunters will likely shift their hunting effort to those species that increase in availability, requiring local and regional organizations to engage effectively with agency in modifying patterns of fish and game management. Development of community gardens or changes in hunting regulations to constrain competition from urban hunters could enhance social-ecological resilience at the local level. Changes in economic conditions, such as employment in rural and urban communities, interact with the effects of climatic change, affecting human migration patterns and human capital of villages. In summary, climate warming and socioeconomic changes challenge the resilience of rural indigenous communities, but indigenous culture has proven relatively resilient to even greater threats over the past century (epidemics of Euroamerican diseases, imposition of Christian worldviews, assimilation policies of education and settlement). Many of the changes described above (e.g., wildfire risk and thawing permafrost) also affect larger communities and cities along the road network of Alaska. However, urban areas are buffered by alternative income sources (jobs) and transportation options (roads) that reduce overall vulnerability. Rural-to-urban migration links villages with cities, putting pressure on public services (especially schools) in the cities but extends social networks of villages to tap urban employment opportunities.


Figure 11: Post docs Todd Brinkman and Shauna BurnSilver leading a focus group discussion with indigenous hunters in the village Venetie, Alaska to document local knowledge of changes to ecosystem services due to climate change.
Section I. Direct effects of climate change on ecosystems and disturbance regimes.

In 2012, we continued to explore the variability in 45 intermediate-aged (40-60 yrs old) hardwood, mixed, and black spruce stands distributed across 7 fire scars. In particular, we looked at the relationship between vascular species composition and environmental variables and surveyed hare browsing on conifer seedlings. We found the largest variability in species composition exists in black spruce stands versus mixed and hardwood stands (Figure 1a). Ordination analysis and multi-response permutation procedure (MRPP) indicate that black spruce stands are significantly different in vascular species composition from mixed or hardwood stands, however hardwood and mixed stands are not significantly different from each other. We also found that the environmental variables that were most strongly correlated with species composition were age of stand and soil organic layer depth (Figure 1a). Because a large proportion of the variance observed in species composition was due to the black spruce stands, we then excluded black spruce from the analysis and found a strong relationship between species composition and fire scar (Figure 1b). In particular, the Gerstle River (GR) and Granite Mtn (GM) fires that are geographically close were very similar in species composition. These results suggest two things. Firstly, there are unique characteristics of each fire (severity, timing of fire, size of fire) that may drive post-fire species composition. Secondly the strong pH gradient coupled with the strong geographic relationship seen may indicate an underlying landscape development-species composition relationship not related to characteristics of fire.

We found percent of conifer seedlings browsed by hares ranged from 0 to 95% among stands, and was higher in hardwood and mixed stands relative to black spruce stands (Figure 2). Browsing was highest in dense birch stands and in stands where understorey alder BA provided cover from predator detection. Stands with high browsing on conifer seedlings also had high mortality of conifer seedlings. These stands also suffered higher mortalities of willow and birch, but moose browsing may have contributed to these patterns. Interestingly, availability of preferred forage did not affect the probability that conifers were browsed, likely because most of the hardwood seedlings had already been consumed by hares. Finally, there were strong indirect effects of overstorey birch BA on mortality of conifer seedlings, willows and birch, through the activities of hares browsing on conifer seedlings. Similar indirect paths link alder shrub cover to mortalities of these species, but less strongly (Figure 3).
Figure 1: NMDS Species ordinations of intermediate aged stands. A) All 45 sites are presented and grouped by stand type (black spruce, mixed, and hardwoods). B) Only mixed and hardwoods are presented and grouped by fire scar. BD = Big Denver, GM = Granite Mountain, GR = Gerstle River, MD = Murphy Dome, WD = Wickersham Dome.
Figure 2: Percent conifer seedlings (< DBH) browsed by hares by stand across hardwood, mixed and black spruce stands with 7 intermediate-age (40-60 yrs old) fire scars. BD = Big Denver, GM = Granite Mountain, GR = Gerstle River, LG = Livengood, MD = Murphy Dome, WD = Wickersham Dome.

Figure 3: Structural equation model showing effects on, and consequences of, percent hare browsing on conifer seedlings in intermediate-aged stands across 7 fire scars throughout interior Alaska. Although data are preliminary and the fit of this particular model is not strong, these ecological relationships are helping to
guide new long-term field experiments and identify methods for browse surveys for our new site network.

Growth of the oldest black spruce at the New Site Network locations Murphy Dome, Big Denver, and Wickersham Dome display a classic negative temperature sensitivity previously established for white spruce in low elevation boreal Alaska (Figure 4). Mean monthly temperatures of May in the year of ring formation and the two previous Julys are highly correlated with detrended ring width. When those three monthly temperatures are combined into a predictive index of temperature the index reproduces most of the features of short, medium, and long term variability (Figure 5). Both temperature favorability and actual growth have declined in recent decades, reaching lowest levels in the instrument-based climate record. The earliest 21st century relationship shows that, unique for the record, short-term recovery in climate favorability has not resulted increased growth of this population, suggesting that either the fundamental relationship is changing, or that the trees are too stressed to recover growth.

![Figure 4. Correlation of monthly temperature at Fairbanks with mean sample ring width index. New Site Network sample - MD, WD, BD black spruce n = 16; 2011-1908)](image)

Figure 4. Correlation of ring width index of oldest black spruce trees from New Site Network sites at Murphy Dome (MD) Wickersham Dome (WD), and Big Denver (BD) with mean monthly temperatures at Fairbanks. The 36 months displayed include August in the year of ring formation (far right) and decrease to the left. Months with significant correlations are highlighted in color, and the three months that most efficiently model growth are highlighted in red.
Figure 5. The temperature index (mean of May monthly mean temperature in the year of ring formation, and July of the two previous years) reproduces much of the annual variability of growth in the population of older New Site Network black spruce at Big Denver (BD), Murphy Dome (MD), and Wickersham Dome (WD).

Patterns of black spruce growth estimated from tree rings at 30 sites sampled in 2011 indicated that black spruce showed a mix of positive and negative responses to increasing summer warmth. Trees showing negative responses in this sample were preferentially found in dense stands on N-facing aspects. These results are contrary to our hypothesis that negative responses would be associated with the warmest topographic positions due to warming-induced drought stress (Lloyd and Bunn, 2007). Ongoing analyses of ring width series samples in 2012 indicate that our two sampling regions differ in topographic patterns of climate sensitivity. Trees in the warmer, more productive sites along the Steese highway showed positive responses to summer temperature at cooler, moister sites, and negative responders were principally found on southern exposures with good drainage. In contrast, samples from cooler forests along the Dalton highway showed the pattern we observed in our 2011 samples, where positive responses of tree growth to summer temperature
were observed at warmer sites, and negative responses were associated with
the cooler, wetter sites. We believe this regional disparity is tied to the
widespread presence of permafrost at the northern Dalton sites, and hypothesize
that cooler sites with shallow permafrost may induce drought stress in trees when
water is immobilized by frozen soil.

Aspen in interior Alaska exhibit a shared pattern of highly variable growth
among years (Figure 6). Years with reduced growth—for example, the late
1960s—are consistent across sites, suggesting common limiting factors.

Figure 6. Standardized aspen ring-width chronologies from four sites in interior
Alaska. Two sites are steep, south-facing bluffs (Bonanza Bluff, Nenana Bluff)
and two are more mesic sites (Bonanza Creek Upland, Ester Dome).

We were able to fit statistically significant models for all of the aspen sites,
and all models indicated that aspen growth was optimum in cool, wet conditions
(Figure 7). In fact, growth was optimum in the extreme cool years at all sites,
particularly for late winter, May, and September. Optimum growth occurred at a
broader range of precipitation values than temperature values, but aspen
preferred wetter years at all sites.
Upland white spruce exhibited a remarkably similar response to climate, with optimal growth occurring in the coolest, wettest years. There were striking nonlinearities in growth response to temperature. For example, at all sites, white spruce growth decreased rapidly as May temperature increased above 5-7°C. Optimal growth for spruce currently occurs in the coolest (Figure 8) and wettest (data not shown) years. For many variables, the optimal range for spruce growth does not overlap with predicted conditions over the next 100 years.
After four measurement years of basal area growth on upland sites and three years on floodplain sites at our long-term snowmelt exclusion experiment, a clear relationship between snow melt recharge of soil moisture and tree growth is still not apparent. In the upland sites significant differences were observed in the first and fourth year of the snow melt removal treatment but no differences were observed in the second and third year of treatment (Table 1). No differences were observed on the floodplain after three years of treatment. Although longer-
term measurements will be required to sort out the role of snowmelt on tree growth, our current thinking on the preliminary results is that snowfall quantities observed in the uplands were a key factor controlling tree growth. The total winter snowfall was relatively low in both 2010 and 2011 (Table 1). It may be that snowfall quantities below 125 mm (water equivalent) result in a significant decrease in tree growth the following growing season. Values above that level result in increased growth when compared to the snowmelt removal treatments (Table 2).

**Table 1. Winter (9/10 – 5/15) and Summer (5/16 – 9/9) Precipitation Quantities (mm)**

<table>
<thead>
<tr>
<th>Year</th>
<th>LTER1 - Upland</th>
<th>LTER2 - Floodplain</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Winter</td>
<td>Summer</td>
</tr>
<tr>
<td>2009</td>
<td>152.4</td>
<td>154.2</td>
</tr>
<tr>
<td>2010</td>
<td>72.1</td>
<td>229.4</td>
</tr>
<tr>
<td>2011</td>
<td>127.5</td>
<td>165.1</td>
</tr>
<tr>
<td>2012</td>
<td>145.5</td>
<td>172.2</td>
</tr>
</tbody>
</table>

**Table 2. Differences in basal area growth between the control and summer drought treatment and between the control and snow melt (winter) removal treatments in upland and floodplain locations.**

<table>
<thead>
<tr>
<th>Growth</th>
<th>Aspen</th>
<th>Birch</th>
<th>Poplar</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>Summer</td>
<td>Winter</td>
</tr>
<tr>
<td>Bag06</td>
<td>4.39</td>
<td>4.02</td>
<td>0.79*</td>
</tr>
<tr>
<td>Bag07</td>
<td>0.61</td>
<td>1.44</td>
<td>0.55</td>
</tr>
<tr>
<td>Bag08</td>
<td>3.72</td>
<td>2.52</td>
<td>-1.07*</td>
</tr>
<tr>
<td>Bag09</td>
<td>6.59*</td>
<td>4.02</td>
<td>0.79*</td>
</tr>
<tr>
<td>Bag10</td>
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<td>0.20</td>
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<tr>
<td>Bag11</td>
<td>0.95</td>
<td>0.64</td>
<td>1.05</td>
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<tr>
<td>Bag12</td>
<td>2.06*</td>
<td>2.16</td>
<td>-1.07*</td>
</tr>
<tr>
<td>Total</td>
<td>12.69*</td>
<td>8.81</td>
<td>2.56*</td>
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<table>
<thead>
<tr>
<th>Growth</th>
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<th>W. Spruce</th>
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<tbody>
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<tr>
<td>Bag07</td>
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<td>Bag08</td>
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<td>Bag09</td>
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<td>Bag11</td>
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<tr>
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<td>2.30</td>
</tr>
<tr>
<td>Total</td>
<td>15.08</td>
<td>9.10</td>
</tr>
</tbody>
</table>

* control vs. winter difference
# control vs. summer difference

Shaded cells indicate the time period for snowmelt removal treatments
**Yearly statistics failed calculation**
Snowshoe Hare Ecology

Population trends
The snowshoe hare population has continued a gradual decline since 2011. By fall 2012 there were still several hares on the Spruce grid, including 12 carrying radio collars. However, by mid-December 2012, our sample population of collared hares was down to 5. The paucity of hares was even greater during Spring 2012 on the Riparian grid as no hares were caught during the standard 4-night trap session. Only 2 hares were caught during the fall trapping session as indicated in the table below, but no hares are carrying collars in this habitat (Table 3).

Table 3. Number of total capture events, estimated population size and population density of snowshoe hares on the Bonanza Creek hare trapping grids Spring and Fall 2012.

<table>
<thead>
<tr>
<th>Habitat</th>
<th># total caught</th>
<th># ind hares</th>
<th>Pop size</th>
<th>Density (hares/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spruce grid</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spring 2012</td>
<td>42</td>
<td>17</td>
<td>17</td>
<td>0.6 (0.1)</td>
</tr>
<tr>
<td>Fall 2012</td>
<td>31</td>
<td>15</td>
<td>18.5</td>
<td>0.8 (0.4)</td>
</tr>
<tr>
<td>Willow grid</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spring 2012</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Fall 2012</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

Survival
Hares on the Spruce grid tend to survive at a greater rate than hares associated with riparian habitats, but over the study period the cumulative rates of mortality have been fairly constant on both grids. Survival typically is higher in the summer than winter, and we typically observe an uptick in mortality at the onset of winter (Sept-Nov) and during the first breeding season (April).
Figure 9. Modeled survival of snowshoe hares 2008-2012 (n=285) in relation to season and habitat based on Kaplan-Meier data using a staggered design.

Survival is also influenced by the body condition of hares. However, this is most evident during seasons when mortality rates are greatest in late fall/spring compared to summer when survival is much higher (Figure 10).

Figure 10. Daily survival estimates of snowshoe hares in relation to body condition and season in Bonanza Creek 2008-2012.
The source of mortality is largely (90%) due to predation. Lynx and goshawks are the major predators, but they are distributed differentially by habitat. Thus, death by predation is mostly due to lynx in the spruce habitat, but largely due to goshawks in the more open riparian habitat (Figure 11).

Figure 11. Sources of predation snowshoe hares in Bonanza Creek in relation to habitat.

Snowshoe hare feeding behavior in relation to plant secondary metabolites

We have completed the study of feeding behavior of captive hares. The focus of the project was to examine how snowshoe hares may alleviate the toxic effects of plant secondary metabolites (PSM) by ingesting mineral soil. The latter may provide important minerals (Na, K, Ca, etc), chelate toxic compounds in clays, or counteract the effects of acidosis via increased circulation of bicarbonate (which may be in high concentrations in soils from mineral licks). Below we illustrate the effects of these interactions from a winter trials with willow stems (Figure 12).
Figure 12. Effects of geophagy (natural lick soil and soil spiked with CaCO₃) on intake of natural winter browse and weight change (left panels) in captive snowshoe hares over 3 separate feeding trials during Oct-Dec 2011.

We conclude that geophagy allows hares to have greater rates of daily food intake which in turn reduce the rate of body mass loss. Whereas the physiological underpinnings of these patterns are not entirely clear, they suggest that acidosis is part of the deleterious effects on PSMs and that both normal soil intake and soil spiked with CaCO₃ alleviate this condition. We will pursue these questions further over the next year on a new project.

Lynx ecology

None of the lynx collared last year resided in the study area after 31 December, 2011. Two lynx are unaccounted for, and the remaining 8 lynx were caught by trappers. Three lynx (1 male, 2 female) were collared in the BZ study area between Aug-Nov 2012. The lynx ranged in body weight from 8.2-10.5 kg. None of the females were accompanied by kittens. All lynx were caught in cage traps and none were subsequently recaptured. Only one male currently resides in the study area. One female was trapped on 12/1/12 and another female dispersed to the west. She was last heard from, by ADF&G personnel doing moose surveys, on 11/26/12 near the mouth of the Kantishna River approximately 80 km west of Bonanza Creek. Lynx tracks have been very scarce in the study area this fall, but coyotes appear more abundant than last year. Despite a scarcity of snowshoe
hares most lynx have exhibited similar movement and activity patterns as earlier in the cycle. Lynx exhibit substantial variation in daily travel rates and typically are most active during the night (1800 - 0600 hr) than during the day as indicated in Figure 13.

Figure 13. Daily travel rates (left) and diel activity (right) patterns of female lynx in Bonanza Creek during fall and early winter. Time periods (P) of activity refer to 3-hr periods past 2400 hr.

The low $\delta^{15}$N signature of lynx, compared to other predators in our study area, is consistent with a diet of snowshoe hares (Figure 14).

Figure 14: Isotopic composition of mustelid, canid and felid muscle tissue obtained from furbearers trapping in interior Alaska.
Our efforts to study lynx (Figure 15) have been somewhat hampered by heavy trapping pressure. All known mortalities of collared lynx (n=21) have been due to trapping within 12 months of initial capture. We are currently seeking funding to expand our wildlife studies to encompass other, less trapped, areas of Alaska.

Figure 15: Lynx recovering from sedation after being outfitted with GPS color along the Tanana River floodplain during December 2012.

Analyses based on the land cover dataset (the National Land Cover Data – NLCD – data set generated from Landsat TM data) showed that for the boreal forest region of interior Alaska, the dominant vegetation cover was shrub and the dominant forest cover was mature spruce (Figure 16a). Overall, mature spruce forests, mixed forests, and shrublands were slightly more prevalent within fire perimeters compared to the landscape as a whole, while deciduous forests and areas with non-woody vegetation were less prevalent (Figure 16b).
Figure 16a. Area of different vegetation cover in the boreal region of Alaska derived from the 2001 NLCD data set.

Figure 16b. Fraction of vegetation cover for the entire boreal forest region of Alaska compared to the fraction of vegetation cover within fire perimeters from 2000 to 2008.

The analyses of satellite data products from 2002 to 2008 showed that the fraction of area burned within fire perimeters did not vary as a function of the size of the fire events (Figure 17a), and averaged 81% overall. The fraction of burned area within a perimeter did vary as a function of vegetation type, with the highest fraction occurring for mature spruce forest (86%) and the lowest for non woody vegetation (68%) (Figure 17b).

Figure 17a. Burned area as a function of fire perimeter area for 169 fire events from 2002 to 2008.

Figure 17b. Fraction of burned area within a fire perimeter as a function of vegetation cover.

Finally, the fraction of burned area of mature spruce forest was examined as a function of topographic position and the timing of the fire during the growing season. During all years studied, some 2.0 million ha of mature spruce forest burned, with most of the burned area (87%) occurring in upland areas (Figure
There was some variation in the fraction of spruce burned as a function of topographic position, with the highest value (90%) for south-facing backslope sites and the lowest value (83%) for north-facing backslope sites (Figure 18a). Most of the spruce area burned occurred in June, July and August, while the fraction of burned spruce area decreased during the growing season (Figure 18b).

![Figure 18a. Spruce area burned and fraction of spruce burned as a function of topographic position.](image)

![Figure 18b. Spruce area burned and fraction of spruce burned as a function timing of the fire during the growing season.](image)

During the beginning of the 2000s, permafrost temperatures within Alaskan Interior were relatively stable without noticeable increase. During the last five years, even some decrease (from 0.1°C to 0.3°C) in permafrost temperatures was observed in the region around Fairbanks (Birch Lake and College Peat sites) and at the Healy site (Figure 19). This decrease agrees with stable or even slightly decreasing mean annual air temperatures (Figure 20) and relatively low snow cover thickness (Figure 21) after the mid-1990s throughout the region. Slight cooling still continues at the Healy site, while at the northern Interior site (Old Man) a slight warming occurred in the last two years.

Results of measurements from the newly installed ground temperature measurement sites along a transect across the Goldstream Creek valley north of Fairbanks show a crucial importance of winter air temperature inversions in the surrounding Fairbanks uplands for the ground temperature regime formation. The difference in mean annual air temperature ranges 3.6°C between the valley bottom and the ridge crest (Figure 22). In addition to the air temperature inversion, the ecosystem type in the valley bottom (tall tussocks tundra) makes permafrost temperature even lower (Figure 23).
Figure 19: Time series of annual permafrost temperatures measured in 1983-2012 from south to north across the Interior Alaska and Alaska and Brooks Ranges.

Figure 20. Mean annual air temperatures (annual averages were calculated for “hydrological year” from October 1 through September 30 of each year) measured at the Fairbanks meteorological station in 1906-2012.
Figure 21. Snow depth measured at the Fairbanks meteorological station in 1929-2012.

Figure 22. Mean annual air temperature averaged for 2010 and 2011 at different locations along the Goldstream LTER permafrost transect.
Figure 23. Mean annual ground temperature at 1.2 m depth averaged for 2010 and 2011 at different locations along the Goldstream LTER permafrost transect.

The ratio of mean ring width of a regional sample of white spruce in central Alaska compared to the 117 tree samples of aspen reveals four periods of uniquely low growth performance of aspen – 1904-05, 1968-70, 1988, and 2001-2010 (Figure 24). The last two dates are within the monitored period at BNZ, and appear to be caused by an outbreak of the large aspen tortrix in 1988. This pattern of shorter term and rapid decline in outbreak populations was typical periodically during the 20th century (Figure 25). By contrast, since the essentially rangewide, sustained outbreak of the aspen leaf miner in 1998 (Figure 26) outbreaks of the large aspen tortrix have not appeared, but aspen growth has significantly underperformed the climate predictive index calibrated to this population. In 2012 for the first time since the beginning of the outbreak in 1998, widespread aspen foliage recovery was obvious in BNZ and remote stands sampled across Interior Alaska. The late 20th century / early 21st century aspen leaf miner outbreak is a unique marker in the 200 year chronology developed at BNZ, and is one of a number of analogous forest stress indicators emerging from the combination of chronologies, empirical studies, and monitoring at BNZ.
Figure 24. Ratio of mean sample ring width of a regional sample of white spruce (6 stands 58 trees) and aspen (7 stands 117 trees) in central Alaska. Ratios above 2.0 are highlighted in red, indicating years of particularly poor relative growth performance of aspen, occurring in 1904-05, 1968-70, 1988, and 2001-2010.

Figure 25. Aspen ring width series from the 3.2 Mile forest reference hectare in BNZ. The collapse in radial growth from 1967-70 represents the effects of defoliation by the large aspen tortrix.
Figure 26. Aspen ring width series from the 3.2 Mile forest reference hectare in BNZ. The sustained reduction in growth from 1998 onward reflects leaf damage from the aspen leaf miner. Reduced growth performance began in 1998 at BNZ, and was pervasive across a regional sample from 2011 through 2011.

Section II. Climate-disturbance interactions as drivers of ecosystem and landscape change.

Climate-driven changes in fire regime interact with environmental conditions and vegetation structure to alter ecosystem function and structure, and successional pathways.

The boreal forests of Interior Alaska have undergone a widespread shift from coniferous to deciduous vegetation that began around A.D. 1990 and will continue over the next several decades (Mann et al. 2012). This ecological regime shift is being driven by old, highly flammable spruce stands encountering a warmer Alaska climate conducive to larger and more frequent fires. Increased burning promotes the spread of deciduous species at the expense of spruce. These modeling results support previous inferences that Alaska’s boreal forest is now shifting to a new ecological state and that positive feedbacks to global warming will accompany this change.

Increased fire size and frequency driven by climate warming may decrease range quality for one of the largest caribou herds in the world, the Western Arctic Herd. Joly et al. (2012) simulated effects of climate change on the
fire regime within the winter range of the Western Arctic Herd, to assess how forage may be impacted. The simulated declines in the quantity of core winter range in the future due to larger and more frequent fires could impact caribou abundance through decreased nutritional performance and/or apparent competition with moose. These impacts would likely be detrimental to the subsistence users that rely on this resource. Additionally, changes in the fire regime and decreases in caribou abundance could amplify feedback mechanisms, such as decreasing albedo, by facilitating shrub growth that may hasten climate-driven changes to the composition and structure of vegetation communities in the low Arctic.

Novel bioinformatic and phylogenetic analyses have revealed that fungal species diversity is 17 times higher than plant diversity in boreal forest, a fungus:plant ratio that is 3 times higher than has been previously estimated. Application of these analytical techniques to other biomes could increase global fungal diversity estimates by an order of magnitude. Taylor et al. (submitted) found that there were 1008 fungal species (OTUs, operational taxonomic units) across the 12 black spruce sites we have studied. The most exciting aspect of this finding is that the rarefaction curves have saturated (Figure 27), suggesting that we have enumerated the entire spectrum of fungal species occurring in these samples. The 1008 fungal species contrasts with only 60 species of vascular plants found across these sites, giving a fungus to plant ratio of ~17:1. This ratio is much higher than previous estimates, and would suggest a global fungal diversity of perhaps 6 million species, if this FP ratio is consistent across biomes. Furthermore, our sampling of 12 sites appears to provide a reliable estimate of the FP ratio for Interior Alaskan black spruce forest, since the ratio quickly asymptotes after the first few sites were added in rarefaction resampling analyses. Hence, our results demonstrate 1) strong and consistent linkages between aboveground and belowground biodiversity in the boreal forest, and 2) much higher regional, and perhaps global, fungal diversity than prior estimates.
In our analyses of one group of novel sequences recovered from BNZ soil clone libraries, which we have named NS1, we found no evidence to suggest that the sequences are artifacts. Instead, NS1 appears to belong to the Fungi (Figure 28) but is so divergent from previously documented sequences that it may represent a Class or Phylum that is new to science. Furthermore, the NS1 sequences have secondary structures, conserved nucleotide motifs, and melting temperatures consistent with those of orthologous ribosomal regions from bona-fide fungi. In addition, the sequences are not of chimeric origin. Hence, we conclude that they represent real organisms. A manuscript describing these findings is under review at Molecular Phylogenetics and Evolution.
Figure 28. Maximum likelihood phylogenetic reconstruction of the kingdom Eumycota based on partial LSU rDNA gene region. Branch thickness is proportional to bootstrap support. The first number above selected nodes is the maximum likelihood support from 1000 fast bootstrap replicates in RAxML; the number following the "/" is the posterior probability from 10,000,000 generations in MrBayes. Only bootstrap values about 70% and posterior probabilities above 80% are shown. When only a number after the / is given, the bootstrap support was below 70% while the posterior probability (shown) was above 80%.

Interestingly, the occurrence of this taxon was statistically significantly spatially clustered in one region of the study site where it was originally discovered (Figure 29). We also found this taxon at several additional upland BNZ sites, but in one of the non-riparian black spruce sites. The occurrence of this taxon was positively correlated with the abundance of white spruce across the upland sites, suggesting the possibility of a highly specific plant-fungal interaction.
A fungus, *Suillus tomentosus*, known to harbor N-fixing microbial symbionts, has been identified in experimentally outplanted lodgepole pine seedlings. This is the first record of this fungus species in Interior Alaska. With respect to joint vegetation-microbe responses to fire, we harvested half of our JFSP outplant seedlings in 2011 and have begun assessing mycorrhizal colonization. All species, including non-native lodgepole, were heavily colonized by ectomycorrhizal fungi. Preliminary sequencing results suggest that lodgepole associates with both native and non-native fungal species when introduced into Alaskan burn scars. Of particular importance, we found the fungus *Suillus tomentosus* associated with lodgepole seedlings from three different sites (Figure 30). We have not previously recorded this fungus in Alaska, either in extensive sporocarp collections or our >100,000 soil clones. To our knowledge, this fungus is specific to *Pinus*, despite the facts that pine has not occurred in Interior Alaska for perhaps 3 million years and that the nearest native populations are over 100 kilometers distant. Given the fact that nitrogen limitation is one of the key stresses in boreal post-fire habitats, reports that *Suillus tomentosus* harbors
nitrogen fixing bacteria in association with lodgepole pine has huge potential implications for pine invasion and its ecosystem consequences.

Non-native, invasive plant species germinated at a higher frequency and grew more rapidly in burned than in unburned black spruce forests, suggesting that increasing fire frequency and size might enhance the expansion of invaders (Frey and Johnstone, unpublished data). *Viccia cracca*, the species with the largest seeds and highest initial growth rates, was the only species to consistently germinate successfully in unburned forest. Seedbed manipulations, where surface moss or litter were removed, increased germination rates for all species, suggesting that vegetation development provides a barrier to successful colonization by seed. The relatively low rates of seed germination on natural substrates in burned and unburned stands are consistent with the roadside surveys, which found low densities of native species even when seed sources were available by the road side. Non-natives were also never observed in the mature forest sites, while they occasionally occurred in burned stands.

At low densities, the invasive exotic plant species *Melilotus* enhances fruit production of the native cranberry by attracting pollinators. At high densities, however, *Melilotus* competes for pollinators, swamping out positive effects (Mulder et al., unpublished data). In an experiment manipulating *Melilotus* density and spatial aggregation, fruit production in *V. vitis-idaea* was significantly greater in all orbits in plots where 40 *Melilotus* plants were added compared to control plots, though again the increase was greatest in the two orbits closest to the center. However, fruit production in plots with 120 *Melilotus* plants added was not significantly different from control plots. Overall, fruit production was much higher.
than in 2011. Overall, the results suggest that distance to invasive patch, patch size, and environmental conditions all influence whether interactions between *Melilotus* and *V. vitis-idaea* are positive, neutral, or negative. Presence of *Melilotus* appears to increase the number of pollinators in the vicinity, resulting in higher numbers of pollinators (based on data from a related project by Schneller and Carlson), but *Melilotus* acts as a strong competitor for those pollinators.

As climate warms, the migration of boreal tree and shrub species into arctic tundra may be accelerated by increasing frequency of disturbances such as fire. The absence of key microbial symbionts, however, may slow or prevent migration (Hewitt et al., unpublished data). Analysis of fungal DNA sequences in samples collected from a tundra fire well beyond treeline showed no evidence of the ectomycorrhizal symbionts of black spruce or alder, the necessary mycobionts associated with these host-plants under undisturbed conditions. Experimental inoculation of with tundra fire soils reduced spruce and alder biomass (Figure 31), and biomass was significantly related to fungal composition. Increasing fire severity altered fungal community composition for spruce- and alder-associated fungi; however, the effect of fire severity on alder-associated fungi was muted by differences in fungal composition between organic and mineral soil horizons. We observed a reduction in inoculum potential along the fire severity gradient for both spruce and alder-associated fungi with an increase in pathogens and a decrease in ericoid fungi and dark septate endophytes as fire severity increased. Alder seedling performance was more sensitive to changes in fungal composition related to fire severity than fire-adapted black spruce suggesting that shrub expansion in the arctic more so than black spruce migration beyond current treeline may be limited by availability of fungal partners under severe fire conditions (Figure 32).

![Figure 31. The effect of fire severity on seedling biomass resident inoculum from post-fire tundra sites.](image-url)
Fire severity is the primary driver of post-fire species composition and key functional characteristics of understory vegetation in the black spruce forests of Interior Alaska (Hollingsworth et al., submitted). Environmental variables such as site moisture, soil pH, and climate were secondary in effect. In addition, variations in post-fire plant community composition were also strongly related to the abundance of different plant traits. Associations with different regeneration modes and rooting substrates were predominantly expressed along the fire severity gradient represented by Axis 1 (Figure 33). Colonizers and species that root in mineral soil were more abundant after high-severity burns, while resprouters and species that rooted in the upper duff and moss layer were most abundant at low-severity sites. Variations in post-fire plant community composition were also strongly related to differences in plant traits such as regeneration strategy and predominant rooting depth. Over 40% of the post-fire species displayed the “resprouter” strategy, making it the most common regeneration mode in the post-fire species pool and species rooting in the lower duff and mineral soil showed a higher than expected proportional abundance after fire. A large portion of species encountered in the post-fire communities were also associated with the “residual” strategy, in which species become part of the post-fire community by surviving in patches of unburned vegetation (Figure 34). Finally, approximately 20% of the post-fire species encountered were classified as colonizers arising from seed (Figure 34). The effect of fire severity as a filter on the distribution of plant regeneration traits can be visualized by comparing the distribution of regeneration traits in different severity classes versus the distribution of traits among species in the entire post-fire species pool (Figure 34). If there were no sorting effects of fire, abundance-weighted distributions of species should reflect the distribution of traits across species in the post-fire pool. In general, fire reduced the abundance of “residuals” compared to their proportional number in the post-fire species pool, and this reduction was
greatest at high-severity sites, where unburned patches were less common. In contrast, the relative abundance of “colonizers” was higher in burned sites compared to their proportional number in the post-fire species pool; this increase was greatest at high-severity sites. Species using the “resprouter” strategy were most common at low- and moderate-severity sites and “residuals” were also most abundant at low-severity sites. For rooting traits, species rooted in the moss layer were less abundant after fire than their distribution in the species pool would predict. In contrast, species rooting in the lower duff and mineral soil showed a higher than expected proportional abundance after fire (Figure 34).

Figure 33. Sites are grouped by fire severity (● = high severity sites, ▼ = moderate severity, and □ = low severity sites), showing Axis 1 versus Axis 2. Strong correlations (r > 0.25) with the ordination axes are indicated by biplot vector where length and direction represent the magnitude and direction of correlation, respectively. Ordination axes were correlated with abiotic and biotic environmental variables (a,b), species composition (c), and plant trait composition (d). Figure provided from Hollingsworth et al.; under review at PLoS One.
Figure 34. Distributions range across the regional species pool of post-fire black spruce communities (a,b) and the realized, abundance-weighted trait distribution in post-fire communities that experience different levels of fire severity (c,d). Two sets of traits related to post-fire regeneration are shown: (a,c) Regeneration mode separated into categories of regenerators, colonizers, and residuals, and (b,d) Distribution of belowground biomass across different rooting substrates (moss, upper duff, lower duff, and mineral soil). For the regional species pool, the distribution of traits has been separated into understory growth forms of lichens, mosses, and vascular plants. Figure provided from Hollingsworth, Johnstone, Bernhardt, and Chapin; under review at PLoS One.

Observations of seedlings that recruited after the 2004 fires indicate that many sites are supporting higher seedling densities and higher rates of tree growth than we originally expected based on pre-fire vegetation structure. These observations support our initial assessment that many sites appear unlikely to return to their pre-fire forest composition, particularly in severely burned areas (Johnstone et al. 2010a). Among our outplanted seedlings, we have observed high rates of growth of native, deciduous trees and non-native lodgepole pine at sites that were exclusively dominated by black spruce prior to the 2004 fires.

At the stand level, a fire-driven shift from black spruce to deciduous dominance may result in greater landscape carbon storage, amplifying the cooling feedbacks associated with higher stand-level albedo. Black spruce stands that shifted to a deciduous successional trajectory after the 2004 fires emitted about 1.5 times more carbon during the fire than stands that returned to
a spruce trajectory after fire (Mack and Johnstone, unpublished data). Over 100 years of post-fire succession, however, deciduous stands accumulated 10 times more carbon in aboveground biomass than spruce stands (Alexander et al. 2012). Although carbon accumulation belowground was three times higher in spruce stands than in deciduous stands over this time period, it was outweighed by the high rates of aboveground carbon accumulation in deciduous stands (Alexander and Mack, unpublished manuscript).

The aspen leaf miner, *Phyllocnistis populiella*, has caused widespread and severe damage to aspen in the boreal forests of western North America for over a decade (Figure 35).

![Figure 35. Typical damage caused by the aspen leaf miner, *Phyllocnistis populiella.*](image)

We suppressed *P. populiella* on individual aspen saplings using insecticide at two sites near Fairbanks, Alaska annually from 2005 to 2011 and compared plant performance to controls annually through spring 2012. Insecticide treatment successfully reduced leaf damage by *P. populiella* during most years and had little effect on herbivory by externally-feeding invertebrates. Treatment did not affect outright mortality of aspen ramets, but at the warmer of two sites (at the Bonanza Creek LTER), ambient levels of leaf mining lead to a high prevalence of top dieback, leaving only one or two new sprouts from the base. At BNZ, 85% of aspen ramets sustaining ambient levels of leaf mining died back to basal sprouts during the study, whereas only 20% of sprayed ramets died back during this time (Figure 36). As a result of the dieback, untreated aspen ramets at BNZ were on average 70% shorter and 57% narrower in girth than treated ramets, and after seven years these trees had lost on average over 1 m of height and 10 mm girth relative to their original, pre-treatment size (Figure 37). At both BNZ and a cooler, high-elevation site,
untreated aspen produced slightly but significantly smaller leaves (3% less leaf area) than insecticide-treated aspen. This was the case for both damaged and undamaged leaves, indicating that the reduced leaf expansion in response to leaf mining was systemic. After 7 years of treatment, untreated aspen at across sites produced more 58% fewer shoots and 49% leaves than controls. We conclude that a decade of *P. populiella* outbreak has caused strongly negative effects on aspen development and the production of aboveground tissues.

*Figure 36. Effect of long-term experimental reduction in leaf mining on the incidence of top dieback by aspen ramets at two boreal forest sites.*
Figure 37. Average size and aboveground tissue production by aspen after seven years of experimental leaf miner suppression at two boreal forest sites. (A) Maximum height of living foliage. (B) Diameter of the main stem at 20 cm height. (C) Number of living shoots. (D) Total number of leaves. Error bars indicate 95% confidence intervals. Asterisks indicate significant differences between treatment and control (P < 0.05).

Recent results from Mike Anderson (Ph.D. graduate) show that Frankia associated with A. tenuifolia in early and late successional stands along the Tanana river belong to a diverse clade distinct from other described Frankia, including Frankia from the same host species in different regions of the US. Distribution of genotypes of this clade across succession confirmed earlier observations that Frankia community composition strongly differs between successional stages in the BNZ, but is consistent within each stage. This study found further differences between successional stages, including differences in Frankia composition within single host plants, in the spatial distribution of genotypes within sampling sites, and in correlations between individual genotypes and several soil variables including pH, and nitrogen and carbon concentration (Anderson et al. submitted to Molecular Evolution).
Figure 38. Frankia phylogeny based on the nifD-K locus. Maximum-likelihood tree based on DNA sequences (753 characters) of the nifD-K spacer locus derived from Alnus tenuifolia (‘AT__’) and A. viridis (‘AC__’) nodules collected in early and late succession habitats in the Bonanza Creek Experimental Forest, interior Alaska. ‘RF’ designations refer to restriction fragment patterns for each sample based on PCR-RFLP of the nifD-K locus. Host species and accession numbers for are given in the tree for comparison sequences downloaded from Genbank. Significant bootstrap values are given as branch labels.

We completed a study to assessed economic trade-offs among N-fixing symbionts of thin-leaf alder (Alnus tenuifolia) examining whether alder-Frankia associations change in response to the up-regulation (P fertilization) and down-regulation (N-fertilization) of N-fixation activities, and whether these changes are associated with differences among Frankia partners in their relative C cost and/or N benefit to A. tenuifolia (Ruess et al. in press). Relative to control plots, alder in +P plots had significantly higher nodule biomass and N fixation rates; these parameters were significantly lower in +N plots, translating to stand-level N inputs that were over an order of magnitude greater in +P than +N plots. Nodule respiration and N fixation rates were positively correlated, and analyses revealed alder employs mechanisms to increase the efficiency of C use when N fixation is up-regulated. Of the 8 Frankia OTUs identified, 2 were dominant, with significant differences in Frankia OTU composition across samples being explained by fertilization treatment. Dominant OTUs had similar up- and down-regulatory responses to treatments but differed in C costs of N fixation, while the most
abundant sub-dominant failed to up-regulate N fixation rates in +P plots (Figure 39).

Figure 39: Effects of N and P fertilization on rates of N fixation for the 2 Frankia dominants (OTU4 and OTU8), and the one sub-dominant found across all treatments (OTU5). Bars within OTUs with different letters represent treatment differences at P < 0.10 (from Ruess et al. in press).

Ecosystem structure and soil drainage characteristics modulate both climate change disturbances to permafrost, and the ecological and hydrological outcomes of changing permafrost.

Our sensitivity analysis indicates permafrost at upland sites is more unstable relative to floodplain sites following severe fire even when vegetation recovery after the fire was considered. An apparent tipping point in permafrost stability can be reached for 30 cm organic layer following a fire of 60% organic layer burn without considering climate warming (Figure 40a). In contrast, permafrost at the floodplain site with an organic layer in excess of 30 cm is resilient to high severity fire (Figure 40b). During the post fire period, high severity forest fires and continuous climate warming of up to +2°C/100years and a steady increase in snow cover thickness can accelerate permafrost thawing at both lowland and upland sites regardless of organic layer thickness (Figure 41a,b).
Figure 40. Simulations of the permafrost table depth for (A) Upland and (B) Floodplain boreal forest sites for different fire severities during stable climate (mean annual air temperatures $-2^\circ C$) using dynamic organic soils recovery rates. Time interval [-10, 0] corresponds to the equilibrium run, and [0, 120] time interval corresponds to the transient run, where 0 is year of a fire ignition.

Figure 41. Simulated permafrost table dynamics after fire for (A) upland and (B) floodplain boreal forest sites during different climate warming scenarios using dynamic organic soils recovery rates and changes in soil moisture content. Time interval [-10, 0] corresponds to the equilibrium run, and [0, 120] time interval corresponds to the transient run, where 0 is year of a fire ignition.
Hydrologic residence time in stream channels was not different between streams draining watersheds with high and low extents of permafrost. At stream discharge < 30 L/s, water residence time within stream channels decreased as discharge increased. However, in the stream draining a low permafrost watershed, residence time increased as discharge increased above 30 L/s. Our evaluation of surface-groundwater interactions in the riparian zone using an end-member model revealed that riparian zone water is a mixture of shallow soil water with high DOC concentration and deeper ground water with lower DOC concentration (Figure 42; Rinehart Ph.D. dissertation, in progress). When thaw depth is shallow the soil water fraction is more important than the ground water fraction.

The riparian zone is metabolically active with the potential to assimilate dissolved organic carbon in the form of acetate rapidly, and the rate of uptake was directly related to hydrologic residence time of water, or in other words, the velocity of subsurface flow through riparian soil (Figure 43). In addition, net uptake of NH$_4^+$ varied substantially across seasons in valley bottoms (Figure 44), but lower net uptake rate in summer, when plants are actively growing, suggests that NH$_4^+$ uptake is balanced with mineralization (Harms and Jones 2012). Net NO$_3^-$ uptake declined sharply from snowmelt to summer, whereas peak denitrification rate occurred during summer. High rates of net NO$_3^-$ uptake and denitrification when flowpaths are restricted to shallow, organic soils indicate a large reservoir for N retention in organic horizons. Rapid rates of N uptake during snowmelt runoff exceeded water residence, indicating potential for retention of N in valley bottom soils during this period, whereas decreased reaction rates in subsequent seasons likely result in N export from soils as the flowpath deepens. Continued deepening of the active layer due to climate warming and permafrost degradation may therefore promote export of DIN to streams.

Nearly a decade after the Boundary Fire burned the P6 subcatchment in the CPCRW, stream water NO$_3^-$ remains elevated and DOC reduced compared to pre-burn concentrations (Figure 45). Based on an end-member mixing analysis of source water contributions to the stream, the proportion of water flowing from organic soil decreased and flow from a mineral flowpath increased after the fire (Figure 46), indicating that either substantial soil organic matter was lost during the fire, or that the seasonal depth of thaw in soil increased.
Figure 42 Mean DOC (panel a) and nitrate (panel b) concentrations in riparian zone and stream water in the Caribou-Poker Creeks Research Watershed (A. Rinehart Ph.D. Dissertation, in progress).
Figure 43. Acetate uptake rate versus hydrologic residence time of water in the riparian zone of the C2 stream in the Caribou-Poker Creeks Research Watershed (A. Rinehart Ph.D. Dissertation, in progress)

Figure 44. Reaction constants (k) for net $\text{NH}_4^+$ and $\text{NO}_3^-$ uptake, and denitrification, measured in saturated valley bottom soils under field conditions. Significant seasonal differences are indicated by lower case letters ($P<0.05$; Harms and Jones 2012).
Figure 45. Change in stream water dissolved organic carbon and nitrate concentrations in the P6 stream of the Caribou-Poker Creeks Research Watershed. Change in concentration is calculated as the difference between the concentration in the P6 stream and a reference stream (C1 stream; A. Olsson Ph.D. Dissertation, in progress).
The experimental warming manipulation (snow addition in winter and removal in spring) at the Healy site has now been underway for several years and we are recording soil temperature differences as we expected in the plots where snow accumulated behind the snow fence. Soil temperatures were 4-8 °C warmer during the winter in the winter warming treatments. This temperature difference disappeared in the early spring when the snow pack was removed, but it resulted in a persistent difference in the depth of thaw throughout the growing season into late September, meaning that accumulated heat in the winter warming persisted for an entire season. This pattern has been repeated each growing season. The addition of summer warming via passive chambers warmed the air but did not alter the soil temperature regime or the thaw depth, much as we expected from previous passive warming experiments. We showed that experimental warming that caused permafrost degradation led to a two-fold increase in net carbon uptake by the ecosystem during the growing season, in line with decadal trends of ‘greening’ tundra across the region. However, warming also enhanced winter respiration, which entirely offset growing season carbon gains. Winter carbon losses may be even higher in response to actual climate warming, and in that modeled scenario, could be expected to more than double overall net carbon losses from tundra to the atmosphere. These results highlight the importance of winter processes in determining whether tundra acts as a carbon source or sink, and demonstrate the potential magnitude of carbon

Figure 46. Change in source water contributions to stream flow in the P6 stream of the Caribou-Poker Creeks Research Watershed. (A. Olsson Ph.D. Dissertation, in progress).
release from the permafrost zone that might be expected in a warmer climate. We have a synthesis manuscript that is in the review and revision stage focusing on these results.

Two years of data from the eddy covariance towers (2010–2012) indicate that the permafrost plateau is a large, consistent CO₂ sink, with approximately 300 g C m⁻² yr⁻¹ of CO₂ uptake during both years (Figure 47). However, we measured large interannual variation at the thermokarst bog. In 2011, the ecosystem was a source of ~150 g C-CO₂ m⁻² between February – October, while in 2012 the ecosystem was a sink of ~70 g C-CO₂ m⁻² over the same time period (Euskirchen unpublished). Causes of the interannual variation are being explored, but might be due to differences in growing season length or hydrology between study years.

![Figure 47. Cumulative net ecosystem exchange at the black spruce peat plateau and collapse bog sites from February – October during 2011 and 2012. A positive value of NEE denotes a source of C and a negative value denotes a sink (Euskirchen, unpublished data).](image)

Because this research is located in lowland environments, quantification of release of soil C as CH₄ is an important research activity. Research from both the Bonanza Creek Experimental Forest and Innoko sites show that permafrost thaw causes large increases in northern wetland CH₄ emissions (Shea, Turetsky et al. in prep; Johnston, Harden et al. in prep; Figure 48). The majority of CH₄ in collapse bogs is released through either aerenchymous vascular plant tissue or
through bubble production (ebullition). The magnitude of these two pathways of transport varies with time since permafrost thaw (Figure 49). The highest total emissions of CH$_4$ was measured in newly formed collapse features (decades) (Johnston, Harden et al. in prep), but across sites ebullition appears to contribute to the buoyancy of surface peat layers and thus likely serves as an important ecohydrology feedback that maintains saturated conditions (Shea, Turetsky et al. in preparation). We used radiocarbon dating to determine that ebullition is predominantly a surface process driven by modern (plant-derived) C. However, about 10-15% of bubble C-CH$_4$ was derived from older permafrost C (Klapstein, Turetsky et al. in prep). This research is important because it shows that permafrost thaw stimulates the release of old C as CO$_2$ as well as CH$_4$.

Research in northern wetlands is a new component of LTER research, and our graduate students only recently have completed their thesis work. We currently have four manuscripts circulating among colleagues for review, with anticipated submission as early as January 2013 (target journals are *Global Change Biology*, *Ecosystems*, *Nature Geoscience*). Together, our results suggest that permafrost thaw in poorly drained environments will alter ecosystem C balance by 1) reducing the carbon sink strength of black spruce forests in peat plateaus, 2) increasing soil CO$_2$ losses, though we have observed large interannual variation in collapse bog CO$_2$ fluxes, and 3) increasing CH$_4$ fluxes with a significant component of old C release. While we originally concluded that enhanced moss productivity following thaw provides a partial offset for enhanced soil C loss, we now find that reductions in black spruce productivity across the landscape following permafrost thaw may over-ride the moss effect resulting in a reduced regional C sink term across lowlands of interior Alaska.

![Figure 48](image_url)

*Figure 48: The contribution of old permafrost carbon in bubble methane increased through the growing season in the youngest BCEF collapse bog, but showed less of a seasonal shift in an older collapse bog (Klapstein, Turetsky et al., in prep).*
Figure 49. The release of methane via ebullition (bubbling) increases with thaw depth as well as warmer soil temperatures in northern wetlands, suggesting that ebullition is an important release pathway of methane in thaw wetlands as well as lakes (Shea, Turetsky et al, in prep).

Section III. Regional ecosystem dynamics and climate feedbacks.

The synchronous coupling of TEM, ALFRESCO, and GIPL has resulted on a design based on loose coupling methods that allowed each submodel in the coupling framework to be maintained independently by each modeling group, with minimal changes to individual code sets. The coupler will consist of a central executable, and each submodel will be managed as a shared library (Figure 50). Changes to each library may be made by each modeling group as necessary with minimal impact to the other modeling groups. Variables and data will be shared as necessary through a mediator object, allowing communication between models to be isolated to specific needs. Upon analysis of individual
tools and development methods, the modeling groups agreed to standardize source code maintenance, operating platform, application build tools, and deployment process for the individual models. Following from that, a number of changes have been made to each submodel to allow the models to work coherently within a common application framework, in order to standardize interaction between the models.

Figure 50: Modeling framework for proposed synchronous coupling among ALFRESCO, TEM and GIPL.

Results from ALFRESCO simulations investigating whether the boreal forest is crossing a major ecological threshold (Mann et al. 2012) indicate the (1) there has been widespread shift from coniferous to deciduous vegetation in interior Alaska that began around 1990 and will continue over the next several decades (Figure 51), and (2) these changes in the vegetation composition and fire regime are predicted to alter the biophysics of Alaska’s forests (Figure 52).
Results from ALFRESCO simulations on the dynamics of treeline indicate that the expansion of white spruce into tundra by 2100 will be limited to within approximately 100 km of the current boundary between boreal forest and tundra (Figure 53; Breen et al. in preparation).

Results from Peatland DOS-TEM simulations (Fan et al. 2012; Figure 54) across two climate simulations for three emissions scenarios suggest that the rate of SOC sequestration in the rich fen will increase between year 2012 and 2061 (Figure 54) because the effects of warming increase heterotrophic respiration less than they increase carbon inputs via production (Figure 55). However, after 2061, the rate of SOC sequestration will be weakened (Figure 54) and, as a result, the rich fen will likely become a carbon source to the atmosphere between 2062 and 2099. During this period, the effects of projected warming increase respiration so that it is greater than carbon inputs via production (Figure 55). Although changes in precipitation alone had relatively little effect on the dynamics of SOC, changes in precipitation did interact with warming to influence SOC dynamics for some climate scenarios (Figure 55). The responses of peatland DOS-TEM suggest that the molar ratio between CO₂ and CH₄ emissions increases under all of the three emission scenarios. The increase in the CO₂:CH₄ ratio is primarily caused by increases in CO₂ emissions and the relative insensitivity of CH₄ emissions (Figure 54).

![Figure 51. Observed, reconstructed, and predicted ratios of spruce to deciduous species. Black dot indicates the spruce/deciduous ratio in 2001 that was estimated from the 2001 National Land Cover Database vegetation classification. Different model spin-up trajectories are shown as dashed lines that rapidly converge, illustrating the model’s robustness under different starting conditions.](image-url)
Figure 52. Predicted biophysical impacts in the Alaskan boreal forest. Previous observations of how biophysical parameters change along post-fire chronosequences in Alaska are integrated with simulations of burning and forest succession to infer changes in (a) summertime albedo and annual net solar radiation, (b) annual sensible heat flux, (c) summertime fluxes of sensible heat and latent heat, and (d) summertime heat flux into the ground.
Figure 53. ALFRESCO output showing tundra converted to spruce forest. Simulated colonization of tundra by spruce is driven by historical (1900-2008) and projected (2009-2100) climate scenarios. The colors indicate areas most likely to convert to spruce forest at different time steps (blue=1900, pink=1950, orange=2000, yellow=2050 and green=2100).

Figure 54. The simulated cumulative carbon sequestration by peatland DOSTEM for ECHAM and GFDL under three warming scenarios (A1B, A2, and B1) from 2012 to 2099.
Figure 55. The simulated soil organic carbon stock change, soil organic carbon input, and CO$_2$ and CH$_4$ fluxes by peatland DOS-TEM for ECHAM and GFDL under three warming scenarios (i.e., A1B, A2, and B1) from Year 2012-2061 and Year 2062-2099. The unit is g C m$^{-2}$ yr$^{-1}$. Factorial simulations were conducted.
Section IV. Coupled social-ecological dynamics of interior Alaska.

Alaskan Rural Village vulnerability to changes in subsistence systems:

We built on the work completed in 2011 to explore factors affecting the impacts of changes in ecosystem services on communities of Interior Alaska. In particular, we were interested in the dependence on a villages’ suite of harvested species and how changes in seasonality may affect subsistence harvesting. Communities harvest different species at different times of year (called the “seasonal round” of harvesting). Using a vulnerability framework, we considered different forms of sensitivity and exposure of subsistence villages to climate change (Figure 56). To make comparisons between communities, sensitivity indicators were defined based on sensitivity-relevant aspects contained in the seasonal rounds. These aspects or indicators are: variety (= how many species can a community target?, and how many distinct ecosystems do I have access to?, and timing (= when can I harvest?, and for how long?). Three indicators of human agency were identified that could be derived from the seasonal rounds data on variety and timing. These secondary indicators are: variety choices: flexibility (= does one have different target resource options?), exclusivity (= does one have to choose between resources?), and opportunity (= can one go and harvest at all?, and can one combine harvesting efforts?); and timing choices: exclusivity and flexibility (= does one have other options to harvest in the year?).

Figure 56. Vulnerability of a subsistence unit of analysis as determined by sensitivity and exposure to climate change

We discovered that the availability of data was a major issue in completing the analysis. Harvest data and information on seasonal rounds for communities are old and in many cases incomplete. In some cases harvested species are listed without sufficient specificity (e.g., “waterfowl” vs. “mallard, black ducks, or Canada geese”). We therefore used the most current and best available data we could find and as needed, collapsed species to create common units of analysis. Data from five Interior Alaska villages (Arctic Village, Dot Lake, Fort Yukon, McGrath, and Venetie) were compared with North Slope villages (Barrow, Kaktovik, Point Hope, and Wainwright).

On the basis of this analysis we found:
• Communities of Interior Alaska have more species available and may therefore be slightly less sensitive to ecological change than North Slope communities.

• However, individual communities are targeting anywhere between 11 and 25 species in the Interior and anywhere between 12 and 24 species on the North Slope, which shows a similar scattered picture for numbers of species targeted in communities in both regions.

• Communities on the North Slope on average target a higher percentage of the total available in the region (47%), and therefore may be slightly less sensitive to change than the Interior communities who target only 42% on average. However, when looking at efficient species (species with a high yield in a relatively short amount of harvest time), the picture becomes quite different: 29% of the species targeted in the Interior vs. 64% of the species targeted on the North Slope are considered efficient – this shows that communities on the North Slope are probably less sensitive than communities in the Interior.

• Regarding timing, in terms of spread of activity for all targeted species, there were no differences between the North Slope and the Interior. However, when looking at spread of species in the Interior vs. the North Slope, the North Slope targets those almost all year long (94% of the time) vs. 75% of the time in the Interior. Interior communities could be as low as 42% of the time and as high as 92% of the time. Salmon are targeted during a very limited time of the year in both regions, and spread varies from 17% (Point Hope) to 42% (McGrath). Coincidence (harvesting two species at the same time) appears to be a big issue in both regions. Interior communities have a coincidence >50% of harvest species during 5.6 months of the year, while North Slope communities have a coincidence >50% during 8.3 months of the year.

On this basis it became clear that in both regions there are communities that are more or less sensitive according to the number of species available. Of those villages studied, in the Interior Alaska, Venetie is the community with the least species to start with, while on the North Slope it is Kaktovik. Both communities should be considered more sensitive than others. However, in terms of exclusivity and coincidence, Venetie is better off than any of the other communities, with 42% of the year targeting only one species at a time. Also regarding efficient species, Venetie scores high on exclusivity and may therefore be less sensitive than could be expected from the number of species to start with - or the other way around.

Social and economic factors affecting resilience:

Our review of social and economic conditions in Interior Alaska drew on preliminary findings of the Sharing Project (mentioned in the activities section).
Our comparison of community conditions yielded findings relevant to resilience. The first we refer to as the “infrastructure trap” which results when a village increases dependency on and expectations for the human-build environment. This condition is characterized by several North Slope villages which have extensive village infrastructure and recently have expressed support for off shore Arctic oil and gas development to maintain the flow of cash resources as a way of sustaining the current standard of living. This condition contrasts sharply with the “poverty trap” of most villages of Interior Alaska, where there are few opportunities in villages for cash resources (including jobs) and few income sources, such as dividends from development interests. These contrasting conditions are also related to the ability of villages to buffer in the face of economic crisis. This difference is illustrated in the 2007 spike in fuel prices. In that case, Interior Alaska communities experienced an extreme increase in fuel costs as compared to North Slope villages that were buffered through subsidies from tax revenues from the oil industry (e.g., Venetie – 629% increase vs. Kaktovik – 300% increase). In our preliminary findings from our studies in Venetie and Kaktovik show how Interior and North Slope communities have a significantly different access to cash resources with both being highly dependent (about 75%) on government for employment (Figure 57).

![Figure 57. Comparison of income levels for households of Venetie (Interior village) and Kaktovik (North Slope village)](image)

The combination of conditions show that Interior villages faced issues related to food security because fuel is used to transport foodstuffs at local stores and to fuel boats and snow machines for hunting. While these communities differ in household income levels and cultural orientation (Inupiat Eskimo vs. Gwich’in Indian), they both engage in extensive cooperative harvesting activities and maintain extensive networks of sharing harvested resources. Cooperative harvesting and sharing were found to account for 75% of subsistence inflows in
both communities. Both also had subsistence resource inflows from households within the community and from non-local sources (other villages) (Figure 58, 59). We hypothesize that social relations and sharing networks serve as a source of resilience during periods of harvesting shortfalls and in turn, sustain cultural traditions, identity, and community.

Figure 58: Own household harvesting vs. cooperating harvesting and sharing in Venetie, Alaska. 92,577 lbs flowed to Venetie households (core species, 12 months); 80,874 lbs was harvested.
Community based monitoring:

Through previous work conducted in Canada and in Arctic Village, Alaska, we found that community-based ecological monitoring, while valuable in informing ecological science, can also be limited in its utility if it exclusively uses qualitative methods. Through a review of past community monitoring, we find that while qualitative methods provide rich and nuanced details about local social-ecological conditions at the local and regional levels, this approach is limited in documenting human perceptions of social ecological change through time with accuracy. In an attempt to identify an optimum approach, we are developing a mixed methods community monitoring interview that provides quantitative results, qualitative insights, and spatially explicit documentation of observations. This work is being tied to our participation in the Maps and Locals working group.
One of the findings of interviews with local harvesters is that access issues (harvesters’ ability to get to harvesting areas) is perceived as more problematic (e.g., fires damaging trail systems, lower river levels making it hard to travel by boat) than issues of resource abundance and distribution. From our initial interviews with seven long-time residents/elders of Nenana, we documented the following observations of long-term change. Data from interviews are now being transcribed and coded; this list represents preliminary findings.

- There are fewer ducks and geese - Most respondents agreed they used to fill the sky and are now only seen here and there.
- Minto Flats area (north of Nenana) has less water. Less ground leads to less mink and muskrat. Some respondents stated that this process started in the mid-late 60’s and has continued.
- Salmon have decreased in abundance. Most say that there have decreased drastically, and talk of time when the boxes of their fish wheels overflowed and the salmon where so thick one could “walk across the river on their backs”.
- Fires seem more frequent which are affecting wildlife.
- There are more willow and scrub brush near rivers.
- There are fewer blueberries.
- Respondents stated that the intense cold periods (minus 70 below) are no more and there is less snow. Most talked about every winter days past of seeing 70 below for a week, which happened almost every winter.
- There is "less spectacular breakup" not the clashing, thrashing, powerful, throw ice 20’ in the air type breakups anymore. One elder said, “The rivers are a lot tamer now. Used to have a boat handy in case of flood.”

Mapping results and quantitative results from interviews are currently being analyzed.

**Synthesis**

We are in the process of drawing on findings from the “Sharing Project”, interview data, and our other studies to construct a model prototype that represents how exogenous drivers of change interact with internal community dynamics and in turn affect the resilience of the village social-ecological system. Figure 60 is our conceptual model of endogenous conditions. The model includes the interaction of household demographics, social organization of harvesting, the dynamics of changing ecosystem services affecting resource availability, and household and community decisions on the redistribution of resources (i.e., sharing). At present we are building a *generic village model*, with the idea that its can be modified to reflect local conditions so comparatives community studies can be undertaken in the future.
Figure 60: Prototype of how exogenous drivers of change interact with internal community dynamics to affect the resilience of the village social-ecological system.
Contributions Within Discipline

1. Through long-term studies of fire cycles and their links to climate, BNZ scientists have documented an increase in fire severity brought on by climate warming that will likely shift the Alaskan boreal forest from a spruce- to a broadleaf-dominated landscape.

Plant ecologists working with the Bonanza Creek LTER program in Alaska have found evidence that the fire regime is changing. Increased fire in late summer is associated with greater consumption of the soil organic layer (Turetsky et al. 2011), altering the ecosystem processes that shape subsequent succession. Typically, plant-soil-microbial (PSM) feedbacks between vascular plants, mosses, and microbial decomposition maintain deep organic soils in black spruce forests and wetlands of Interior Alaska (Johnstone et al. 2010a). This internal feedback has been a key source of ecosystem resilience under the historical fire regime. Fires in poorly drained ecosystems with moist, cold soils leave much of the soil organic layer intact (Turetsky et al. 2011), generating seedbeds of thick moss or peat that favor the re-establishment of black spruce and mosses. The system usually quickly returns to a structure similar to that of the conifer-dominated, pre-fire forest.

However, the stabilizing feedbacks between plants and soil in the boreal forest can be disrupted by severe fire events. When less than about 5 cm depth of organic soil remains after fire, northern ecosystems become more vulnerable to regime shifts, including permafrost thaw and altered vegetation succession. After severe fires, deciduous tree species such as aspen and birch can establish at high densities (Johnstone et al. 2010b). From long-term studies of forest succession at the Bonanza Creek LTER sites, scientists have found that this period of initial post-fire succession sets the stage for decades to centuries of plant succession. Thus, the change in seedbed conditions caused by a severe fire can catalyze a switch from conifer dominance to alternate plant successional trajectories dominated by deciduous trees.

Once deciduous forests are established, a new domain of PSM feedbacks emerges where shallow organic soils are maintained by rapidly decomposing litter from highly productive deciduous species. Deciduous broadleaf trees increase rates of evapotranspiration and export moisture from the soil to the atmosphere. Once thick organic layers are consumed by fire, permafrost degradation is likely, leading to a state change that permanently alters ecosystem structure and function. Shifts between domains of spruce vs. deciduous dominance and the resulting effects on permafrost have large implications for ecosystem productivity and carbon storage, feedbacks to regional climate - the goods and services that boreal ecosystems provide to humans. Indeed, BNZ scientists have shown that shifts from conifer to deciduous forest cover can at least partially compensate for the carbon emissions caused by increasing wildfire (Randerson et al. 2006). This research demonstrates that stabilizing feedbacks within the dominant forest type can be disrupted by changes to climate and disturbance regimes, initiating rapid transformations of the forest landscape, with regional to global consequences.


Figure 1: Large fires in the boreal forests of Alaska may stimulate transitions from black spruce (see the patch of unburned trees in the foreground) to a landscape matrix dominated by deciduous tree species. Photo taken near the Caribou Poker Creek Research Watershed of the Bonanza Creek LTER site.
2. BNZ scientists have discovered that the thaw of permafrost induced by climate change is causing the rapid decomposition of previously frozen organic carbon in boreal forest soils. This CO\textsubscript{2} release is likely to amplify climate warming to the same extent as land use change worldwide.

At least 1218 Pg (billion tons) of soil carbon (C) are stored in surface permafrost soils in boreal and arctic ecosystems, almost twice as much C than currently contained in the atmosphere (Tarnocai et al. 2009). Latitudinal gradients of soil C storage, field experiments, and laboratory incubations all show that soil C cycling in these northern ecosystems is likely to be strongly influenced by the effect of cold temperature on rates of decomposition of soil organic matter. This 'old' soil C, climatically protected from microbial decomposition in frozen or waterlogged soil, has been accumulating in these ecosystems throughout the Holocene, and for much longer in some unglaciated areas. The BNZ LTER report results from a tundra landscape undergoing permafrost thaw, where net ecosystem C exchange and the radiocarbon age of ecosystem respiration were measured to determine the influence of old C loss on ecosystem C balance (Schuur et al. 2009). Sustained transfers of C to the atmosphere that could cause a significant positive feedback to climate change must come from old C, which forms the bulk of the permafrost C pool that accumulated over thousands of years (Schuur et al. 2008). Areas that thawed over the past 15 years had 40\% more annual losses of old C compared to minimally thawed areas, but had overall net ecosystem C uptake as increased plant growth offset these losses. In contrast, sites that thawed decades earlier lost even more old C, a 78\% increase over minimally thawed areas, which contributed to overall net
ecosystem C release despite increased plant growth. These data document
significant losses of soil C with permafrost thaw that, over decadal time scales,
overwhelms increased plant C uptake at rates that could make permafrost a large
biospheric C source in a warmer world, similar in magnitude in the future to current
C fluxes from land use change. At present, increasing greenhouse gases responsible
for climate change are largely a result of human activities. However, climate change
may alter the natural cycling of carbon in ecosystems far from direct human
influence. This research is key for understanding how terrestrial system feedbacks
will interact with human emissions, and may influence policy-driven emission
mandates aimed at controlling the overall rate of climate change.

2008. Vulnerability of permafrost carbon to climate change: Implications for the

2009. The effect of permafrost thaw on old carbon release and net carbon
Soil Organic Carbon Pools in the Northern Circumpolar Permafrost Region.

Figure 3: Photograph of typical thermokarst feature in the Noatak Valley, Alaska.
3. By tracking seasonal changes in snow cover for decades, BNZ scientists have discovered that the snow free season in the boreal forests of Alaska is lengthening and likely to speed the rate of warming by increasing the amount of light energy absorbed by the land surface.

Modeling simulations over boreal Alaska have documented changes in albedo due to changes in the duration of the snow season and due to changes in the amount of young forest stands on a landscape due to changes in the fire regime. In addition, changes in the exchange of the greenhouse gases CO₂ and methane have also been estimated due to changes in climate, atmospheric carbon dioxide concentrations, fire regimes, and methane emissions. The sum of these feedbacks indicates that changes in boreal Alaska acted to warm the atmosphere between 1970–2000 and between 2003–20100. The strongest feedback to climate warming was derived from a lengthening of the growing season (reducing the snow-albedo feedback) between 2003–2100, and this was only partially counterbalanced by the cooling effect of an increase in the amount of young stands in the landscape under more severe fire regimes, and increases in carbon uptake by terrestrial ecosystems between. Furthermore, under a warmer, wetter climate the amount of methane released from Alaska’s peatlands increased between 1970 – 2000 and between 2003 - 2100, acting as an additional positive feedback to climate warming.


Figure 5: Changes in the duration of the snow season represent a strong positive feedback to climate warming due to the contrast in surface reflectivity between snow-covered and snow-free ground.

Figure 6: Summary of changes in atmospheric heating due to changes in land surface albedo and carbon and methane uptake/emissions in boreal Alaska, from available estimates. A negative sign represents a negative feedback for a sink term and a positive sign represents a positive feedback for a source term. From: Euskirchen et al., 2010.
4. **Nitrogen is an essential nutrient that plants need to live and grow.** BNZ scientists have discovered that boreal plants acquire nitrogen through a variety of mechanisms, including uptake from hyporheic water and direct uptake of organic compounds such as amino acids.

Biogeochemical investigations have a long history at BNZ. These studies have demonstrated how slowly soil organic matter turns over in boreal forest soils because of low biological activity coupled to a very short growing season. Recently, however, we have learned that nitrogen cycling in boreal forest soils continues past freeze-up and that about 40% of the annual nitrogen flux occurs during winter. Whereas decomposition and nitrogen mineralization may appear slow compared to more temperate ecosystems (Jones and Kielland 2012), there are other avenues of soil N supply which support vegetation demand across primary succession on the Tanana River floodplain. For example, the production and turnover of dissolved organic nitrogen in boreal forests appear to be as rapid as that of inorganic nitrogen, and the uptake of amino acids by plants and microbes appears equally important as the uptake of dissolved inorganic nitrogen (Kielland et al. 2006a, McFarland et al. 2010). Soils on the Tanana River floodplain exhibit both qualitative and quantitative shifts in biogeochemical processes across succession. Early successional soils which have low organic matter content are characterized by low in situ rates of nitrogen mineralization and proteolysis (Kielland et al. 2006b).

Riparian vegetation derives most nitrogen from nitrate supplied via hyporheic flow (Clilverd et al. 2009, Koyama and Kielland 2011). Nitrogen mineralization increases with increasing soil organic matter content, reaches a peak in mid-succession, and declines thereafter possibly due to an accumulation of recalcitrant soil organic matter derived from the dominant coniferous tree species. By contrast, soil proteolytic activity and the turnover of free amino acids increases steadily across succession despite marked reductions in soil temperatures (Kielland et al. 2007). This diversity of biogeochemical processes is reflected in qualitative changes of the nitrogen economy of successional vegetation. Thus, early successional, riparian species such as willows rely to a large extent on nitrogen in the form of nitrate supplied by sub-surface water flow (Koyama and Kielland 2011). Mid-successional species absorb nitrate (from river water), and ammonium and amino acids derived from soil. Late successional conifers appear to take up nitrogen in the form of amino acids and ammonium derived from soil organic matter turnover (Kielland et al. 2006a, Näsholm et al. 2009). The substantial range of biogeochemical processes controlling plant nitrogen supply, and the large variation in the forms of nitrogen taken up by boreal forest species suggests that these forests may be more resilient to disturbance, such as climate change, than has hitherto been posited.


Figure 7: Mid-successional balsam poplar trees rely on several mechanisms of nitrogen acquisition, including nitrate uptake from hyporheic water, ammonium from soil N mineralization, and direct uptake of free amino acids in the soil.

Figure 8: The production of free amino acids via proteolysis increases across success ion from the warm, alkaline soils of deciduous shrub stands to the acidic, permafrost-dominated stands of black spruce. From: Kielland et al. 2007.
5. For more than 20 years, BNZ scientists have studied the hidden impact of browsing on ecosystems by conducting experiments that exclude moose and snowshoe hares from large areas. Results show that browsing controls which plant species dominate, how large some trees grow, and how rapidly nutrients cycle through the ecosystem.

Studies of the interactions between vegetation processes and mammalian herbivory have been part of BNZ LTER research for over 20 years. We have found that browsing by moose and snowshoe hares controls vegetation development and nutrient cycling at a variety of scales. Mammalian herbivores control species composition, nutrient cycling, and plant population dynamics at the stand and landscape levels, and these effects are manifested both in early and late succession via herbivore effects on the interaction of biotic and abiotic processes. Primary succession on the Tanana River floodplain is initiated by plant establishment on newly formed silt bars formed by flooding. Whereas all the major plant species (willows, alder, balsam poplar, and spruce) are present in this early wave of colonization, the successional trajectory is characterized by distinct vegetation stages reflecting the life history traits of these dominant species. Because of their high population densities in interior Alaska, mammalian herbivores may consume over 50% of the current annual growth. Consequently, they have major impacts not only on plant growth but also on nutrient cycling processes since litter from browsed plants tends to have higher nutrient concentrations and faster decomposition rates. Perhaps the largest effect of herbivory on nutrient cycling is the selective browsing by moose and snowshoe hares on willows, which leads indirectly to the dominance of alder, an important nitrogen-fixing species that is chemically defended against herbivory. Thus, plant secondary metabolites greatly affects plant-herbivore interactions. During periods of high snowshoe hare density, browsing on seedlings of late-successional species such as white and black spruce can result in effects on forest community composition that persist for decades. Studies of snowshoe hare populations at BNZ have shown that, in addition to the classical decadal population cycle, hare abundance varies nearly as much on an intra-annual basis, underscoring the large oscillations of resource availability in boreal forests.

The effects of mammalian herbivory can also alter the activity and abundance of insects and other arthropods. For example, the longer shoots produced by browsed willows experience higher rates of sawfly infestations than the shorter shoots on mature-growth form plants. Moreover, the generally warmer and drier microclimate on the forest floor, caused by browsing-induced changes in canopy structure, results in altered composition in the guilds of ground-dwelling insects. Thus, mammalian herbivory exerts significant control over biogeochemistry and successional dynamics at the level of the species, community and the ecosystem.
Figure 9: Moose are commonly encountered by BNZ research personnel during winter. Despite high rates of predation by wolves and resident hunters, the moose population in the Tanana Flats is amongst the highest (~1 moose/km²) in North America.

Figure 10: Changes in alder and willow abundance (expressed as leaf litter biomass ratio) in the presence (blue) and absence (red) of mammalian herbivory on the Tanana River floodplain.


6. Successful study of the dynamics of social-ecological systems requires engagement with local communities through meaningful partnerships and processes that facilitate an exchange of knowledge between scientists and local knowledge holders in ways that can inform decision making.

Changes in climate and fire regime are already affecting rural Alaskan communities where indigenous people have historically led a subsistence lifestyle as hunters, fishers, and gatherers. Local residents are observing firsthand that warming has changed the timing of freeze up and melting of rivers and reduced the thickness of river ice and therefore reduced the safety of winter travel and access to some hunting grounds. Increased evapotranspiration and lower river levels reduce opportunities for barge delivery of fuel and increase the cost of living and therefore the dependence on subsistence harvesting. Now that communities are permanently situated rather than semi-nomadic, the increased wildfire risk caused by warmer drier conditions is substantially affecting rural communities. Wildfire is a risk to life and property, reduces access to the land, threatens
cultural and historic resources, and reduces moose and caribou abundances for one to several decades. Sources of resilience to address these changes include local residents’ knowledge of village homelands, oral traditions transmitted by community elders, cooperative harvesting strategies, and sharing networks that maintain community identity while sustaining food supplies to the most vulnerable households and allowing hunters to borrow hunting equipment. As LTER research seeks to improve understanding of social-ecological system dynamics and the options for successful human adaptation, research partnerships are critical in improving science and demonstrating the relevance of research to society. In Interior Alaska rural residents typically spend considerable time on the land and have a rich historic and nuanced understanding of local conditions. Local residents’ scale of observation and understanding can differ from larger scale analyses such as those undertaken with remotely sensed imagery. While “integration of knowledge” is an interesting option for research collaboration, it is not a simple or speedy enterprise. Processes that 1) involve local knowledge holders in science through community-based ecological monitoring, 2) address the problem of scale by linking local knowledge mapping with GI Science of land-cover land-use change, and 3) make use of decision support systems, such as scenario analysis and participatory simulation modeling, offer considerable promise. These transdisciplinary approaches to science and community engagement represent an important frontier in science that is worthy of more experimentation and application.


Figure 11: Post docs Todd Brinkman and Shauna BurnSilver leading a focus group discussion with indigenous hunters in the village Venetie, Alaska to document local knowledge of changes to ecosystem services due to climate change.
I. Direct effects of climate change on ecosystems and disturbance regimes

Hypothesis 1: Changes in temperature and precipitation are influencing ecosystem structure and function at multiple temporal scales through effects on key species, functional types and disturbance regimes, resulting in modifications to landscape structure and heterogeneity.

Task C1: Quantify the influence of site drainage and stand age on the climate sensitivity of vegetation communities and ecosystem function within black spruce forests at the regional scale.

We analyzed the initial batch of tree-ring samples taken from black spruce trees in 2011 at 30 sites (n=5-10 trees/site) across interior Alaska. In the summer of 2012, we conducted more extensive sampling of black spruce along the Steese Highway (near Fairbanks) and Dalton Highway (north of Fairbanks and south of the Brooks Range) to verify preliminary findings from the 2011 samples. Drainage classes ranging from well-drained sites on upland ridges, to poorly drained sites in valleys were used to stratify sites for sampling in black spruce forest (N=6 sites/drainage class * 4 drainage classes). Disks from 10 randomly selected, black spruce trees were collected from each site, sanded, and measured to obtain annual ring widths following standard dendrochronology procedures. Our next step will be to analyze C isotopes in wood samples from positive and negative responders in both regions and assess whether isotope ratios are consistent with our assumption of increased drought stress in negative responders.

In 2012 we continued the process of establishing a new site network of post-fire sites. In particular, to incorporate the full range in variability in intermediate aged stands (40-60 years old), we established an additional 8 intermediate age class sites from 3 fire additional fire scars in interior Alaska: Livengood (1958), Granite Mountain (1954) and Goldstream (1966), and these sites combined with our 2011 sites to produce a total of 47 Intermediate aged stands (Figure 1). We initially selected stands that spanned a gradient of canopy composition ranging from deciduous to conifer that were of various site moisture/drainages. To best capture the range of variability in site drainage, we grouped sites based on their topographic position (uplands vs. lowlands) and parent material (rocky, sandy substrates vs. loamy, peaty substrates). Within this matrix, we captured various densities of deciduous versus coniferous dominance as expressed on the landscape.

Rapid assessments were done at each site (see Annual report 2011) to characterize the vegetation and soil characteristics for each stand (including composition, density, fire history, and herbivory). Preliminary results from analysis suggest the strong influence of fire scar, herbivory, and parent material on vegetation composition and structure. In particular, we began the critical investigation on the influence of herbivory on successional trajectories.

From a remote sensing perspective, little is known about patch-scale variation in contribution to the regional trend in declining NDVI. We used a time-series of Landsat sensor NDVI normalized from 1986-2009 to investigate declining NDVI trends at the
Bonanza Creek Experimental Forest (BCEF) and Caribou-Poker Creek Research Watershed (CPCRW). We determined the trend of mean NDVI at a hierarchy of scales including landscapes (upland, floodplain, lowland), by topographic class, and by vegetation class. We also computed the NDVI trend for each 30-meter pixel at both study areas.

Figure 1. Map of fire scars and intermediate aged sites chosen for the new site network.

Task C2: Based on tree-ring measurements and historic satellite data, determine trends in productivity from a longer temporal and larger spatial perspective.

Research looking at the productivity of aspen is continuing by various senior investigators. A total of nine aspen study sites were established between 2010 and 2011 with a goal of site selection to maximize the length of the ring width record from aspen. All stands were on generally south-facing slopes and between 11 and 14 aspen trees were cored at each site. Final measurements, crossdating and QA procedures were completed for an additional 117 aspen disks from 7 widely separated stands in central and eastern Alaska.

Four of the aspen sites (Ester Dome, UP2C, Bonanza Bluff and Nenana Bluff) and seven interior white spruce sites have been measured, crossdated, and subjected to dendrochronological analyses to define climate response. This analysis was done as
part of a related project (Lloyd, NSF grant ARC-0902088). In an effort to quantify nonlinear growth responses, which are likely if there are thresholds in tree response to climate, we used generalized boosting model (GBM) framework to construct boosted regression trees. We developed boosted regression tree models describing aspen response to fourteen climate variables, representing mean monthly temperature and total monthly precipitation in each of seven time periods: September, early winter (October-January), late winter (February-April), May, June, July, and August. Analyses of spruce growth response to climate used the same climate predictors as the aspen analysis, but summer temperature was considered in aggregate (June-August mean or total). The models used the CRU spatially interpolated dataset (Climate Research Unit, version 3.1) for climate predictor variables. We used the regression tree models to define the range of temperature and precipitation values at which growth was optimum. For white spruce, we then compared those optimal ranges to the predicted distribution of future climate, based on an average of five GCMs.

In 2012 four new aspen sample sites were added in roadless areas along the Lower Tanana River and in the Yukon River canyon north and west of BNZ, with disks cut from 39 trees. Late in the period disks were obtained from an additional 4 sites and 28 trees collected from the road system in the Copper River Valley south and east of BNZ. The goal of the river bluff samples is to provide diverse coverage of sites similar to Bonanza Creek but with independent stand origins and to sample along a westward gradient of cooler summers. The Copper Valley samples are designed to test climate sensitivities south of the Alaska Range outside the Interior boreal climatic region. The BNZ aspen collections now extend across nearly 500 km east to west, and nearly 300 km north to south, and the Copper Valley samples will extend an additional 200 km to the south. Two of the 2012 aspen stand samples were sanded and measured. The earliest ring in the aspen from the remote river sample identified to date is from the early 20th century, but earlier samples nearer Fairbanks were among the oldest (225+ yrs) for the species. All aspen stands had residual levels of damage from aspen leaf miner, but for the first time since 1998 some trees had normal leaf mass of undamaged leaves.

Supplemental core collections of 33 floodplain white spruce trees were obtained from three remote sites on the lower Kantishna River, middle Tanana River, and the Yukon River Canyon. Sampling was focused on filling geographic gaps in a floodplain transect across the large rivers of Alaska. The 2012 cores were prepared and measured, and combined with previous samples for a total of 36 stands and 540 trees extending nearly 1000 km from eastern Interior to the western limit of tree growth along the Yukon River. The combined sample is called the Grant River Transect (GRT). Detrending options for the GRT were defined using a new technique of comparison with an existing 13C master chronology from BNZ. A comprehensive database was developed for the GRT and analysis of climate sensitivity along the gradient was begun, using First Order weather station data from Fairbanks, McGrath, and Bethel.

The majority of support for both the aspen and floodplain tree ring sampling efforts was provided by completion of the USGS Yukon River Basin project and the new Alaska DNR project BAKLAP (Boreal Alaska – Learning, Adaptation, and Production) focused on wood biomass energy issues. Supplemental support was provided by NSF through one of the 2 BNZ REU students, coordination with past BNZ dendrochronology collections and data bases. The 2012 collections by the UAF tree Ring Lab totaled 183
trees including 90 white spruce, 10 black spruce, 16 Alaska birch, and 67 aspen. Some of these included monitoring of tree growth at Research Natural Areas matched to reference stands at BNZ, including Caribou Crossing, Serpentine Slide, and Big Windy Hot Springs. Measurement of previously collected samples, including the NSN involved measurement of about 150 more chronologies. A cooperative project with BLM included measurement of 557 white spruce tree ring chronologies collected by BLM along the entire length of the three largest clearwater rivers in east central Alaska – Birch Creek, Beaver Creek, and the FortyMile River. Continuing effort was also directed toward designing and filling an MS Access database of thousands of previous tree ring collections and measurements in order to do the large geographical scale comparisons required for the current BNZ LTER program.

From the remote sensing perspective, we were guided by previous NDVI results in filling tree ring sampling geographic gaps. Preliminary analysis of aspen ring growth compared to MODIS-derived NDVI did not show a good relationship, probably due to leaf miner damage.

**Task C3: Manipulate the amount and seasonal timing of soil moisture availability to assess influences on productivity of dominant coniferous species.**

In 2011 a stable isotope study was initiated to document the vertical distribution of water sources that trees in both upland and floodplain systems are utilizing. Soil temperature and moisture dynamics have been monitored for the three and four years prior to treatment establishment on the upland and floodplain sites, respectively. Annual diameter growth for all trees on the plots was measured for the past three and four years prior to treatment on the upland and floodplain sites, respectively. Yearly measurements of all trees greater than 2.54 cm at dbh continued in 2011.

Additionally, over the last two years, we have expanded the scope of this component to include consequences to belowground carbon dynamics and storage. This work has two main components: 1) Estimating the total belowground carbon flux (TBCF), and 2) Partitioning soil respiration into autotrophic and heterotrophic components using bomb-derived $^{14}$C as a tracer. These efforts are ongoing, and the estimated completion date is May 2012.

**Task C4: Document the effects of climate variability, vegetation type, and predation on vertebrate herbivore abundance along a latitudinal boreal transect.**

Research on animal ecology during 2011 focused on moose, snowshoe hares and lynx.

**Moose**

We have finalized a population model for moose, which simulates their responses to climate and predation. The model is a stage-structured matrix model with 5 age groups with animals at two nutrition levels, 2 predation scenarios and 3 climate scenarios. The model will be used to aid management of moose in interior Alaska and will be presented to the Alaska Board of Game. A BNZ graduate student is currently preparing manuscript for submission.
In order to better understand the implications of insect outbreaks on ecosystem function and successional processes, and to investigate possible interactions between insect herbivory and patterns of vertebrate browsing, we have set up a long-term manipulative experiment (See Task C7 and Task D11 for further details). During summer 2012 we measured species composition, growth and insect damage on 4 species of willow commonly browsed by moose and grazed by the willow blotch miner.

We continue to monitor species composition and leaf litter fall in the large long-term moose exclosures, which have been in place for over 20 years. In addition we measured browsing intensity and mortality on white spruce recruitment across 10 smaller exclosures on the Tanana River floodplain. This companion study has been going on for 10 years.

**Snowshoe hares**

Our monitoring program of snowshoe hare populations now spans 14 years. In 2012 we had two primary trapping sessions (spring and autumn) to estimate population size and density using mark-recapture methods. We also conducted several trapping sessions to redeploy radio collars on hares for our ongoing mortality study in relation to environmental conditions and habitat use. Moreover, we deployed several experimental GPS collars on hares to examine activity and movement patterns in relation to weather phenomena. The intensive (4-year) portion of the mortality study has been completed, but we will continue to collar hares during the low of the population cycle. A BNZ graduate student is currently writing up the papers emanating from this study.

Data from our four trials to measure field metabolic rates of snowshoe hares in relation to temperature have been analyzed. These experiments were carried out over 4 broad temperature regimes; -10C, -20C, -30C, and -40C, which reflect the typical temperature range experienced by snowshoe hares in winter in interior Alaska. This was the first study of its kind in Alaska.

During 2012 we also completed a study of the interaction between snowshoe hares and plant secondary metabolites (PSM) in their forage. The hares were kept in an outdoor facility under natural ambient light and temperatures, but they were protected from wind and precipitation. The focus of the project was to examine how snowshoe hares may alleviate the toxic effects of plant secondary metabolites (PSM) by ingesting mineral soil. The latter may provide important minerals (Na, K, Ca, etc), chelate toxic compounds in clays, or counteract the effects of acidosis via increased circulation of bicarbonate (which may be in high concentrations in soils from mineral licks). Feeding trials were conducted both in summer and winter using the major forage species and plant tissue typical of the particular season. A BNZ graduate student is currently writing up data from this study.

**Lynx**

As part of the mortality study of snowshoe hares we examined habitat use, movement rates, and activity patterns of lynx in Bonanza Creek Experimental Forest. Lynx were captured in cage traps and fitted with GPS collars. The collars recorded animal locations on a 5-hour fix schedule. In addition the collars recorded temperature,
elevation, and activity. This study along with hare monitoring work is being expanded to northern Alaska in collaboration with the National Park Service and USGS. One high school student was mentored as part of this research, whose project focused on a mathematical analysis of lynx movements presented at the Alaska High School Science Symposium March 2012.

**Task C5: Determine whether key aspects of the fire regime covary in space and time, and if the sensitivity of fire regime to climate is consistent across different ecosystems and landscapes.**

As part of a related NASA funded project to Kasischke, we have begun processing additional data to study landscape-scale patterns of fire activity in the boreal forest region of Alaska, in particular fire events in 2001, 2009, and 2010. In addition to the data that have already been processed, this will provide data over a 10-year period (2001-2010). Once these data have been processed during the upcoming year, we will complete the analysis and submit the results for publication.

**Task C6: Examine the relationship between seasonal and interannual variability in climate and permafrost temperature across a range of ecosystems, and couple these observations to model projections using future climate scenarios.**

In order to place climate sensitivity and successional processes in a common conceptual framework, we have been working towards determining the effects of seasonal and interannual climate variation, disturbance legacies, and subsequent vegetation development on soil temperature, moisture, and permafrost regime. To achieve this goal, we continued our efforts to record and archive data on active layer and permafrost temperature dynamics at our sites within Fairbanks area. This year, we visited sites within the southern portion of the Alaskan transect to collect air and ground temperatures and soil moisture data from the data loggers. Active layer depths and other environmental characteristics were also collected. We measured permafrost temperatures in some deeper boreholes (60 to 80 m) within the southern portion of the transect and in the Fairbanks area. The work on transferring our knowledge, which was gained in permafrost dynamics research into the development and implementation of an evaluated soil-freezing/thawing module in TEM model, was continued. We worked together with D. McGuire’s group on the comparison between their modeling results and our site-specific and spatially distributed models and field data. During the reporting period we upgraded some 4 of the existing sites and added 2 new sites to our Permafrost Observatories Network in the Fairbanks region. In 2008, 8 new sites with air, surface and shallow (down to 1.5 m) soil temperature measurements were established along a transect across the Goldstream Creek valley. The transect starts on the top of a ridge north of the valley and ends on a hilltop on the south side of the valley. The measuring sites are located on every major landscape units across the valley. Using observed data at the Bonanza Creek LTER sites, we also performed a number of calculations of the thermal effect of warming climate on permafrost. Several runs were made where we investigated the effect of different thermal properties of soil organic layer and surface vegetation cover on permafrost dynamics for the 2010-2100 time
period. We used the GIPL permafrost model to assess the effects of changing climate on ground temperature for several major ecosystem types in the Interior Alaska.

Task C7: Assess historical patterns of insect and pathogen outbreaks, and determine how recent summer warming and associated plant drought stress are affecting insect herbivore populations and outbreaks of key plant pathogens.

As described in C2, the accumulation of a sufficient number of aspen tree ring chronologies across a large enough geographic expanse, for the first time provides the opportunity to compare outbreak history of aspen damaging (aspen leaf miner) or defoliating (large aspen tortrix) insects. During 2012 we developed a climate predictive relationship for boreal Alaska aspen, using the 117-tree sample described in C2. To determine suspect years for defoliating insect attacks, we examined the negative anomalies of the detrended, normalized growth of aspen from the climate-predicted growth. As a cross validation tool, we compared the ratio of growth of regional samples of white spruce and birch (unaffected by the aspen leaf miner) compared to the regional sample of aspen. These procedures allowed the identification of the past century of probable and monitored aspen defoliation episodes. James Kruse (USDA Forest Service, State & Private Forestry, Forest Health Protection) has continued the collection forest insect population data from the long-term monitoring plots established by Richard Werner several decades ago, and we are now working with Jim and his group to coordinate a insect monitoring program for our New Site Network.

II. Climate-disturbance interactions as drivers of ecosystem and landscape change

Hypothesis 2a: Climate-driven changes in fire regime interact with environmental conditions and vegetation structure to alter ecosystem function and structure, and successional pathways.

Task D1: Determine the historic fire return interval for key vegetation types, stand ages, and landscape positions, and examine the potential for positive and negative feedbacks between changing vegetation composition and fire frequency.

ALFRESCO modeling efforts over the past year have focused (1) on model developments to further link climate, vegetation succession, and wildfire regime for boreal, treeline, and tundra ecosystems, (2) on model experiments to understand the indirect effects of future climate scenarios on boreal fire regimes and the response of boreal vegetation, and (3) model experiments to understand the interactions of climate, vegetation, and wildfire on wildlife habitat.

Task D2: Determine how the establishment and persistence of key plant species post-fire are regulated by microbial communities, plant interactions, and herbivores.

We are continuing to examine the relationships between aboveground (plant) and belowground (fungal) diversity in the boreal forest. One component of this effort
has been a continuation of our analyses of the large fungal soil PCR-clone datasets generated from the core BNZ sites. For a series of 12 black spruce sites, we have now fully analyzed over 30,000 fungal soil clones in relation to data on plant community composition and a range of other environmental variables. One focus has been the relationship between fungal and plant species diversity. A landmark meta-analysis of plant and fungal diversity across well-censused sites in the United Kingdom revealed that fungus to plant (FP) species ratios were quite consistent on this regional scale. The regional ratio of 6:1, when extrapolated globally, gave an estimate of 1.5 million species of Fungi on Earth (Hawksworth, 1991). This estimate was far higher than most prior estimates, and has become the ‘textbook’ number. However, the estimate did not include molecular data, and so was likely an underestimate for many reasons. We have re-evaluated the Hawksworth estimate using our thorough molecular sampling.

We have also continued our phylogenetic and ecological analyses of novel fungal lineages that were discovered via the soil clone studies in BNZ. In particular, we evaluated whether two extremely unusual soil clone sequences are likely to have originated from real organisms, or instead, represent some sort of artifact. There were two major components to these analyses. First, we carried out rigorous phylogenetic tree reconstruction using 5.8S and LSU ribosomal gene regions in an effort to establish the placement of these sequences within the Eukarya. Second, we used a variety of techniques to model the secondary structures of portions of these sequences in comparison to orthologous sequences from other fungi to evaluate whether the novel sequences obey expected structural constraints on functional ribosomal gene regions. In tandem, we designed taxon-specific PCR primers and analyzed the distribution of this putative novel lineage across plant community types within BNZ. The data on taxon occurrence were analyzed using spatial autocorrelation as well as logistic regression.

We carried out molecular analyses of a subset of ectomycorrhizal root tips from the Joint Fire Sciences Program project seedlings collected in the summer of 2011 (field collections described in last year’s annual report). Seedlings of white spruce, black spruce, aspen, birch and lodgepole pine were planted in the burn scars of several major fires that occurred in Interior Alaska in 2004. Note that lodgepole pine is not native to Interior Alaska, but is slowly migrating northward in a post-glacial expansion. This species has been widely planted in Interior Alaska, and appears more resistant than white spruce to increasingly warm and dry summer conditions in the boreal forest. Furthermore, it is highly adapted to a short fire return interval. Thus, lodgepole pine could become an important species on the landscape in Interior Alaska due to combined effects of climate change, migration and human silvicultural practices. However, we currently have no information on whether fungal symbioses (especially ectomycorrhizae) may act to constrain or facilitate lodgepole expansion, or how lodgepole may affect microbial community composition and function.

Black spruce, *Picea mariana* (Mill.) Britton, Sterns &Poggenb is the dominant boreal tree species in interior Alaska, and *Alnus viridis* ssp. *fruticosa* is one of the shrub species that has increased in biomass with high-latitudinal warming in the Arctic. The presence of these host species at and beyond their current range limit may be determined by the availability of ectomycorrhizal fungi symbionts, which are critical to seedling nutrient acquisition, and the availability of these mycobionts may be altered by climate-driven changes in the fire regime at high-latitudes. Led by PhD candidate
Rebecca Hewitt, we investigated how the successful establishment of alder and spruce seedlings may be controlled by the availability of suitable mycobionts after fire in a growth chamber experiment using resident inoculum from post-fire tundra sites.

As part of Erin Julianus’ thesis, we began a study investigating the interactions between time since last fire and moose habitat in Kanuti National Wildlife Refuge. Moose are not only a keystone species that affects vegetation succession, but also one of the main subsistence resources for the village of Allakaket that borders the refuge. Therefore, understanding the vegetation patterns that drive moose location is a critical management need. Moose are generally considered to be herbivores that rely on mid-successional stands populated predominately by Salix and Populus species; therefore, we would expect the 1990 burn scar to provide the best habitat and food resources based on density, biomass, and quality. The goal of the 2012 summer field season was to quantify summer browse production based on density of browse species within burns, browse biomass in terms of current annual growth of browse species, and nutritional quality of browse species in burns. We accessed burn scars various ages along the Kanuti River (1972, 1990, and 2005, and unburned sites) and established vegetation plots where understory vegetation and fire history was characterized. In the spring of 2013, we plan to revisit sites to measure winter browse at each site. We can then compare potential browse with actual browse and link these comparisons to a variety of physical and biological factors.

Hollingsworth and Johnstone completed research examining the composition of early post-fire vegetation communities following the 2004 fire season, the largest annual area burned in Alaska’s 58-year record. We were interested in whether variations in fire severity would affect community composition by altering the relative success of plant regeneration strategies after fire. We measured environmental conditions (elevation, latitude, longitude, slope, soil pH, site moisture), plant community composition, and regeneration strategy at 87 post-fire sites across interior Alaska. Every species at a site was classed as residual (did not burn in the fire and remained alive after fire), resprouter (burned in the fire and then resprouted from stems or roots), or colonizer (recruited from seed via dispersal or the local seedbank). If a species occurred in two different regeneration modes at a site, the relative proportion of individuals arising from each regeneration mode was estimated based on plant morphology and size. In addition, we measured rooting depths of all vascular species found in four unburned and eight burned plots. We then calculated the frequency of occurrence of dominant regeneration modes for each species and classified species by their predominant rooting layer (moss, upper duff, lower duff, and mineral soil) across all 87 sites. From these data, we completed a multi-variate analysis to determine how strong of an influence disturbance characteristics are on post-fire community assembly.

Previous research by LTER graduate student Katie Villano-Spellman indicated that post-fire sites may be susceptible to invasion by non-native plants. To expand on this research, and test the hypothesis that human and natural disturbances may be facilitating this expansion of non-native plants, we initiated a new set of invasive plant surveys and a seeding experiment in recently burned (2004/2005) and mature black spruce forests. Surveys of invasive plants were conducted adjacent to roadsides along the Dalton (north of Fairbanks) and Parks (west of Fairbanks) highways. Surveys were randomly positioned areas of road side that had a presence of non-native species and
intersected burned or mature black spruce forests. Vegetation and environmental
ccharacteristics, and the density of non-native plants, were recorded along 100-m
transects oriented perpendicular to the roads. Statistical analyses of these data are
currently underway.

Expansion of non-native species into natural forests is largely dependent on
colonization by seed. Thus, variations in seed bed quality and germination success
could affect the susceptibility of different forest habitats to invasion. To test the effects of
specific forest seedbeds on non-native seed germination, we conducted a seeding
experiment in burned and unburned black spruce forest located in the Caribou-Poker
Creeks Research Watershed. Natural (moss, litter) and manipulated (surface layer
removed) seedbeds were marked within each forest type, and 10 replicates of each
seedbed were treated with seeds of one of three common, non-native species that differ
in seed size: *Viccia cracca* (large seeds), *Melilotus alba* (intermediate seeds), and
*Taraxacum officinalis* (small seeds). The plots were caged with wire mesh to prevent
animals from transporting seeds out of the plots. Seeding trials were established in early
June 2012 and germinants were surveyed three times during the summer. The
experiment was harvested in August 2012.

During the 2011 field season we set up an experiment to test the impact of the
presence of flowering *Melilotus alba* on pollination and fruit set in *Vaccinium vitis-idaea*
(cranberry) and *Vaccinium uliginosum* (blueberry). At 18 sites (8 at the Bonanza Creek
LTR and 10 at the Caribou-Poker Flats LTER) we marked plants in orbits around a
central point. Orbits were 1-2 m, 3-5 m, 8-10 m, 15-20 m, and 25-40 m away from the
central point, and each contained 5 plots with 5 *V. vitis-idaea* and 3 *V. uliginosum*. At 12
of these sites a group of 40 flowering *Melilotus alba* plants in containers (grown in a
greenhouse) were introduced at the center point during the berry flowering periods and
removed when berry flowering was (almost) complete. The remaining 6 sites functioned
as controls. Pollinator activity at each site was observed during a 4-hour period, and
some plants were videotaped. Flowers were collected from focal berry plants and from
randomly selected *Ledum groenlandicum* individuals in each orbit prior to and following
*Melilotus* outplanting, and pollen on three stigmas per individual were counted and
identified to species. Number of fruits on focal plants was counted in the field and a
random subset of fruits collected for seed counts. In the 2012 field season, we added
two new field sites and removed two at which flowering rates were too low, resulting in 8
sites at the BNZ LTER site and 10 sites at the CPCRW LTER sites). We repeated the
*Melilotus* outplanting experiments with one design change: we used three levels of
*Melilotus* additions (0, 40, or 120 plants), each implemented at 6 sites. We dropped
*Vaccinium uliginosum* from consideration and instead focused on *Vaccinium vitis-idaea*
and *Ledum groenlandicum*. Procedures were as in the previous year except that
number of stigmas collected as increased.

We expect the total impact of *Melilotus* on *Vaccinium* species to depend on the
extent to which flowering periods overlap, and this is likely to differ depending on
geographical location. To determine the extent to which there is overlap in flowering
periods in the state of Alaska currently and in the future (as plants invade new areas),
and to evaluate variation over space and time, we are using historical records to
develop models linking plant phenology to climate (cumulative degree days and
precipitation). We evaluated the phenological stage of specimens of these three species
in the collections of the University of Alaska Museum, the University of Washington Museum, the New York Botanical Gardens, and the Canadian Museum of Nature in Ottawa. Only specimens from Canada or states bordering Canada (with the exception of a few mountains in New Hampshire and Vermont), with dates and locations, and that were in flower or fruit, were included in the datasets. This resulted in approx. 950 *V. vitis-idaea* specimens, 750 *V. uliginosum* specimens, and 430 *Melilotus* specimens in the dataset. Climate data will be added to the dataset and used to predict flowering time across latitudes. In addition, we tracked phenology of approx. 90 common insect-pollinated plant species at both the BNZ and the CPCRW LTER sites between late May and late August 2012 to examine overlap between native and non-native species in phenology.

Ruess and a Ph.D. student completed several studies characterizing *Frankia* partner choice in thin-leaf alder (*Alnus tenuifolia*) across succession, how partner choice is driven by the cost:benefit of individual partners across succession, and how *Frankia* partner choice is affected by experimental up-regulation (P fertilization) and down-regulation (N-fertilization). Another BNZ graduate student is finishing up her work on P-mobilizing enzymes of individual ectomycorrhizal partners of alder, and how the mycorrhizal communities and enzyme activities vary across succession and in response to P fertilization.

**Task D3: Determine the effects of an altered fire regime on successional trajectory.**

We have continued investigations of long-term monitoring sites established in black spruce forests that burned in 2004. A network of 90 sites was established in burned black spruce forests in 2005 across three large fire complexes in interior Alaska, including 10 sites in the Caribou/Poker Creek Research Watershed. These sites were intensively monitored from 2005-2008 to collect initial observations of environmental conditions and vegetation recovery, and have resulted in several publications (Johnstone et al. 2009, 2010a, Bernhardt et al. 2010, Boby et al. 2010). As part of an externally funded SERDP project (led by Schuur and Mack), we returned to the sites in 2011 to collect additional field data and samples of soil and vegetation. To date, we have completed laboratory processing of the 2011 samples and are beginning to develop statistical models to analyze these data. Models will focus on linking fire severity and environmental conditions to multi-year measures of post-fire tree germination, growth, and survival.

**Task D4: Determine the ecosystem and landscape consequences of an altered fire regime.**

We continue to monitor the ecosystem consequences of fire severity and successional trajectory across three age classes of sites: early successional (all burned in 2004; see task D3), mid-successional (20-60 years in age), and late successional (60+ year old sites). In 2012, we processed plant and soil data collected in 2011, synthesized results and published manuscripts.
To evaluate the role of plant-soil-microbial interactions in stabilizing alternate trajectories of succession that may be initiated by fire, we established a new set of manipulative experiments in mid-successional stands. Within one intermediate-aged fire scar, we located spatially interspersed patches of forest that were dominated by either spruce or birch and had similar slope, aspect, and parent material. To better understand effects of stand composition on ecosystem structure, we measured biomass, aboveground net primary productivity, foliar nutrients, coarse woody debris, understory species composition and biomass, and soil carbon and nitrogen pools in these plots. Functional assays included litter traps for estimation of litter fall and resin bags for relative fluxes of dissolved inorganic nitrogen or phosphorus. We established a reciprocal litter bag transplant experiment between the two stand types to assess differences in litter quality, the microenvironment for decomposition, and their interactions. We deployed micrometerological stations to monitor radiation, air and soil moisture. Finally, we set up a moss transplant experiment to test controls over moss productivity between the stand types.

Hypothesis 2b: Ecosystem structure and soil drainage characteristics modulate both climate change disturbances to permafrost, and the ecological and hydrological outcomes of changing permafrost.

Task D5: Examine the relationship between organic soil layer remaining following fire and permafrost temperature across a range of ecosystems, and couple these observations to model projections using future fire and climate scenarios.

During 2012, we were working on evaluating the issue of whether ecological feedbacks to fire regime play a role in the degree to which soil organic horizons and permafrost integrity in interior Alaska are vulnerable to climate warming. To evaluate this issue, we coupled a landscape-level model that represents interactions between fire regime and forest composition to a biogeochemical model that represents interactions between the dynamics of organic soil horizons and soil thermal regime and then to our site-specific permafrost model GIPL-2. This model was applied for interior Alaska conditions for a climate warming scenario through the 21st Century. Output from DOS-TEM model was used to prescribe the surface vegetation and organic layer thicknesses changes (recovery) after a forest fire and these properties were used in GIPL-2. From these simulations we analyzed changes in organic soil horizon thickness, soil thermal dynamics, and permafrost dynamics in relation to the warming from 1980 - 2100. We examined the controlling factors that can affect the thermal state of permafrost following fire (the post-fire thermal state of permafrost) in an empirical modeling-sensitivity analysis framework in a 120-year post-fire period. These factors were climate, burn-severity, organic layer thickness and soil moisture content. To evaluate the impact of fire on permafrost conditions, we performed a control run of calculations with GIPL-2 model for the 1980-2100 time period in which the surface vegetation and the organic layer depth and properties were kept the same as for 1980.
**Task D6: Examine the coupling among permafrost distribution and thaw, and soil and vegetation structure on watershed hydrology and stream export of C and N in upland boreal forest catchments.**

Our research activities in 2012 focused on understanding nutrient and dissolved organic carbon (DOC) retention in streams, understanding the hydrologic and biogeochemical interactions between streams and riparian zones underlain by permafrost, and continuing our long-term monitoring of stream discharge and stream chemistry within the Caribou-Poker Creeks Research Watershed (CPCRW). To measure in-stream solute retention, we conducted short-term solute injections of conservative (NaCl) and reactive (e.g., ammonium, nitrate, acetate) tracers. Data from solute additions were analyzed to estimate nutrient spiraling metrics to describe solute uptake rates. In addition, we conducted push-pull assays in riparian wells to measure DOC uptake and nitrogen transformations. Push-pull assays involve withdrawing (“pulling”) groundwater from wells, amending with conservative and non-conservative tracers, and then injecting (“pushing”) the solution back into the well. Water samples were subsequently “pulled” over time to measure the disappearance of tracers, which were used to model uptake of DOC and/or transformation of nitrogen species. Our long-term monitoring of fluxes of water and solutes has been focused in five headwater streams and their sub-catchments (C1, C2, C3, C4 & P6 sub-catchments), and at three higher order stream sites (including Caribou Creek, Poker Creek & Poker Creek downstream of the confluence with Caribou Creek). The headwater streams drain watersheds with permafrost extents ranging from 3 – 54% and include one sub-catchment that burned in the Boundary Fire in 2004 (P6 sub-catchment). At each of the stream sites, water samples were routinely collected throughout late spring, summer and early fall; at the five headwater streams, water samples were collected daily using autosamplers, whereas at the higher order sites, grab samples were collected every two weeks. Water samples were analyzed for anions (SO$_4^{2-}$, NO$_3^-$, NO$_2^-$), cations (Ca$^{2+}$, Mg$^{2+}$, K$^+$, Na$^+$, NH$_4^+$), total dissolved nitrogen (TDN), dissolved organic carbon (DOC), dissolved inorganic carbon (DIC), electrical conductance, and pH. Coupled with the chemistry measurements, we monitored stream flow at four of the headwater streams (C2, C3, C4 & P6), and three of the higher order sites (CJ, PJ, PC). In addition to the stream studies, we monitored snow accumulation, and assisted with operation of a NADP site in CPCRW.

**Task D7: Examine the effect of natural and manipulated permafrost thaw on vegetation structure, and ecosystem C and N cycling in upland boreal tundra landscapes.**

We have completed four years of our experimental warming manipulation, and are now midway through the fifth winter. The fourth summer (2012) saw a great deal of activity measuring carbon fluxes and monitoring environmental conditions in the summer and winter warming plots. Similar to 2011, a field crew was located at the field site in April when the snow from the winter warming treatment was removed. This summer was marked by one postdoc (Sue Natali) leaving for a position at the Woods Hole Research Center, and another postdoc (Kirsten Coe) joining the group upon her graduation from Cornell. By early May, we installed the passive greenhouses that
remained on the summer warming study plots through the end of September. During the summer, the field crew made measurements of carbon fluxes and isotopes using static and auto chambers, and of vegetation composition and productivity using non-destructive point-intercept measurements and an LAI camera. We also monitored soil temperature and moisture sensors, and have been continuously recording environmental data including depth of thaw and water table. Additional measurements were done to assess nutrient availability, and common substrate decomposition rates. These suite of measurements were made on the four experimental treatments: summer warming, winter warming, annual (summer+winter) and the control plots, and will be continued for the duration of the project. In addition to growing season measurements, we spent a lot of time installing a system for measuring winter fluxes using multiple approaches including, soda lime, and direct flux measurements both on and off plot. This information is critical for extrapolating treatment differences in winter soil temperature on carbon fluxes. Two students, one a summer REU, spent the fall and early winter (through mid December 2012) at the field site collecting late fall and early winter respiration data. Another student, Elizabeth Webb, entered the graduate program at UF with a focus on these data for a M.S. degree. Now we have multiple forms of winter respiration measurements, including an eddy covariance tower so that we are confident of our extrapolations over this period where fluxes are relatively low and difficult to measure. Because the winter period is so long, accurate estimates for winter respiration influence whether we interpret the tundra site to be a C source or sink on an annual basis.

Another major activity during the summer of 2012 was the continuation of a dry down experiment that manipulated the water table that is perched at the permafrost surface. Water barriers had been installed at the end of the 2010 growing season within the winter warming treatment. This was motivated by data showing interesting changes in moisture as a result of ground subsidence from warming. Sue Natali received an OPP postdoctoral research fellowship based on manipulating water table; in this project year she wrote a full proposal around this manipulation in collaboration with Schuur and this was funded by OPP. In 2011, this manipulation was fully underway by midsummer, so 2012 was the first summer where we manipulated water table throughout the entire growing season. Elaine Pegoraro, an undergraduate at the University of Florida, finished her honors thesis in late spring 2012 focusing on litter quality. At the time of this report, we are just starting to plan the Year 5 field campaign to remove the accumulated snow and to install the passive greenhouses for the summer warming.

Task D8: Examine the effects of natural and manipulated permafrost thaw on vegetation structure and ecosystem C and nitrogen cycling in boreal wetland landscapes.

Over the past several years, we have monitored vegetation composition and productivity, hydrology, and CO2 and CH4 fluxes in a lowland black spruce peat plateau underlain with permafrost near the Bonanza Creek Experimental Forest. We have made similar measurements in adjacent collapse scar bogs formed after permafrost thaw and subsequent thermokarst. We have made measurements in four distinct collapse scars that range in age (time since permafrost thaw), allowing us to examine a young (<100yr) chronosequence of ecosystem succession following thaw. Eddy flux,
autochamber, and manual flux measurements allow us to calculate GPP, NEE, and ER along the chronosequence, and radiocarbon measurements of ecosystem respired CO$_2$ and CO$_2$ from soil incubations are also allowing us to partition ecosystem respiration into autotrophic and heterotrophic components. In addition, soil cores from this permafrost thaw chronosequence are being analyzed in order to calculate the loss of forest silvic peat and the accumulation of bog peat following thaw. These soil-based C accumulation values will be compared to field flux values and soil incubation measures of carbon lability. We have also focused on various aspects of anaerobic decomposition processes in the thermokarst bog, including rates of anaerobic decomposition and linkages to terminal electron accepting processes and microbial communities, rates of methane production and oxidation, and pathways of methane release (diffusion, ebullition, or plant-mediated). In sum, these activities allow us to examine net changes in C storage and greenhouse gas fluxes following permafrost thaw, and the mechanisms driving these changes.

In one of the collapse scars and in an adjacent fen with no permafrost history, we are manipulating water table position and surface soil temperature, allowing us to examine the direct effects of altered soil climate on aspects of lowland ecosystem function. In addition to the Bonanza Creek Experimental Forest lowland sites, four distinct collapse scars at Innoko Flats National Wildlife refuge were studied. The Innoko site is another permafrost thaw chronosequence but ranges in age from up to 1000 years. Measurements at this more remote chronosequence included C and N stocks, water chemistry, and periodic trace gas fluxes.

**Hypothesis 2c: Climate-driven changes in outbreaks of defoliating insects and plant pathogens affect successional pathways and ecosystem function by altering the abundance of key plant species.**

**Task D9: Coordinate monitoring of the abundances of native and invasive insects and pathogens with measurements of plant growth, community composition and stand structure.**

In order to better understand the impact of changes in herbivorous insect populations on ecosystem variables, we are working to more closely link our annual surveys of forest insect and pathogen abundance with ongoing measurements of forest production and species composition, and with regional surveys conducted by the USFS. Aerial insect abundance surveys are conducted annually by the US Forest Service’s Forest Protection Program. During 2012, we met with USFS personnel directing the aerial survey program in interior Alaska, and they have agreed to modify their annual surveys in such a way as to overlap with some of the sites within our New Site Network (NSN) (see Task C1) in order to link our stand-level surveys with outbreak dynamics occurring at the regional scale. Site selection for the NSN is complete, and our plots will be included within the flight lines for the areal program next summer. In addition, we will be implementing a insect/pathogen monitoring program across our NSN in coordination with State USFS personnel beginning next summer.
Task D10: Quantify the effects of alder canker on N-fixation inputs and associated rates of plant growth and successional patterns of C and N storage.

The outbreak and spread of the alder stem canker, and associated impacts on N-fixation inputs, successional processes, and ecosystem function are controlled by a complex interaction among climate warming, disease epidemiology, and alder population dynamics. Because vertebrate herbivory on willows favors alder growth and the incidence of canker increases with alder density, temporal and regional variation in browser abundance appear to indirectly influence disease-related declines in N fixation inputs. We continue our long-term canker monitoring plots to document disease effects on alder growth and mortality, N fixation rates, nodule biomass and N-fixation inputs.

In 2009 we initiated a willow-removal experiment to test its effects on alder recruitment along the Yukon River, where heavy predation by wolves and bears maintains low moose numbers and high willow densities that prevent alder stand development. Stem canker is nearly absent from alders growing along the Yukon River, but this may change if increased willow browsing permits dense alder stands to establish. These long-term experimental plots were revisited in August 2012. All willow and poplar shoots were clipped to 50 cm above the soil surface, and alders were counted and measured for DBH and height.

Task D11: Manipulate the abundance of insect and vertebrate herbivores in early successional stands and assess consequences for plant growth, biogeochemical cycling, and vegetation development.

Insect outbreaks have caused severe damage to deciduous tree and shrub species in the boreal forest during recent years. An outbreak of the aspen leaf miner (Phyllocnistis populiella) on quaking aspen (Populus tremuloides) is now in its 15th continuous year (US Forest Service 2011, Werner & Kruse 2011). Feeding damage by *P. populiella* has decreased photosynthesis and growth rates, and increased the rate of ramet die-back relative to insecticide-treated ramets. In addition, several intense outbreaks of the willow leaf blotch miner (Micrurapteryx salicifoliella) have occurred in interior Alaska as well over the past 20 years; the most outbreak flared in 2009 and was still ongoing in 2012. Ambient levels of attack by *M. salicifoliella* reduced the growth rate of susceptible willow species. Further climate warming is likely to intensify the frequency and intensity of such insect outbreaks.

The willow leaf blotch miner (*Micrurapteryx salicifoliella*) undergoes periodic, regional outbreaks in interior Alaska and has caused severe damage to at least 10 species of willow in interior Alaska in the past five years. In spring 2012, we launched a long-term experimental manipulation designed to test the interactive effects of invertebrate herbivory, such as that caused by *M. salicifoliella*, and vertebrate browsing on plant performance, community composition, and ecosystem processes. We established six sets of paired mammal exclosure and control plots in willow-dominated early successional habitat on the Tanana River floodplain dominated by *Salix* species. Plots were surveyed for plant species cover, community composition, and individual plants were marked for future growth measurements. Subplots within plots were sprayed with insecticide to reduce invertebrate herbivory. Leaf litter was collected to
assess leaf production and litter quality. Measurements of woody tissue production and browsing by mammalian herbivores are scheduled for winter 2012.

III. Regional Ecosystem Dynamics and Climate Feedbacks

Hypothesis 3a: Responses of boreal ecosystems in interior Alaska to projected changes in climate and disturbance regimes will directionally shift vegetation distribution towards more deciduous forest cover primarily through increased disturbance frequency and severity, leading to successional pathways that allow regeneration by deciduous tree species at the expense of conifer tree species.

Task CF1: Couple the model of fire regime with the model of ecosystem structure and function, incorporate information developed from Hypotheses 1 and 2 into the coupled model framework, and conduct a retrospective analysis of the coupled model framework.

See Task CF4 below

Task CF2: Apply the coupled model for future scenarios of climate for interior Alaska and analyze changes in ecosystem function/structure at the regional scale.

See Task CF4 below

Hypothesis 3b: The responses of water and energy exchange associated with changes in climate and disturbance frequency and severity throughout the 21st Century will result in 1) positive feedbacks to climate warming during the shoulder seasons, and 2) negative climate feedbacks during summer, with net positive feedbacks over the annual cycle.

Task CF3: Analyze water and energy feedbacks among the applications of the model to future change in climate for interior Alaska.

Hypothesis 3c: Boreal ecosystems of interior Alaska will lose C as CO₂ to the atmosphere as a result of increased disturbance frequency and severity and increased decomposition because of permafrost thaw, with the response to disturbance dominating the overall flux. CH₄ emissions of boreal wetlands will change because of warming-induced increases in methanogenesis and drainage-induced decreases in methanogenesis, with the former response dominating the overall flux.

Task CF4: Conduct factorial experiments with the modeling framework for future scenarios of climate change in interior Alaska to evaluate the relative effects of climate and disturbance on estimates of CO₂ and CH₄.
In 2011 our activities focused on an asynchronous model coupling of the Alaska Frame Based Ecosystem Code (ALFRESCO), the Dynamic Organic Soil version of the Terrestrial Ecosystem Model (DOS-TEM), and the Geophysical Institutes Permafrost Lab (GIPL) Model. In 2012 we have focused on the development of a synchronous coupling of these three models (see Figure in Findings). We have also worked on the further development of ALFRESCO to better represent processes involving treeline dynamics and on the further development of DOS-TEM to represent vegetation dynamics (DOS-DVM-TEM) and peatland carbon cycling (Peatland DOS-TEM). We have conducted studies with ALFRESCO to evaluate (1) whether the boreal forest of Alaska is crossing a major ecological threshold and (2) how latitudinal treeline may change during the remainder of this century. We have incorporated the results of a field water table manipulation experiment conducted in a boreal rich fen (Task D8) into peatland DOS-TEM and have conducted factorial experiments with the model to understand how soil organic carbon of the rich fen might respond to projected climate change.

IV. Coupled Social-Ecological Dynamics for Interior Alaska

Task SE1: Identify the suite of services most critical to sustainability in interior Alaska.

We worked with the Department of Fish and Game/Division of Subsistence to review available reports and datasets on harvested species of rural communities in Interior Alaska and focused on data for seven Alaskan communities. Based on the ADF&G reports and data, we compiled a DB to identify all species referenced in the DB and evaluated those species with respect to their contributions to total pounds harvested. We developed a framework for assessing the vulnerability of communities to changes in seasonality (e.g., later snow fall and freeze up, earlier thaw). We operationalized concepts of exposure and sensitivity, two of three key components of vulnerability analysis (with adaptive capacity) with several sub components including, # of available species and their variety, # of available efficient species, # of available habitats to target, spread of species over the year, and windows of exclusive opportunity. Examining the full suite of harvested species we assessed conditions and the implications of a changing fire regime to three of these communities. We also analyzed the data gathered from the “The Study of Sharing Networks to Assess the Vulnerabilities of Local Communities to Oil and Gas Development Impacts in Arctic Alaska” (funded by BOEM – Department of Interior) that applied social network analysis methods to understand the mixed cash-subsistence economies of three Alaskan villages. The data from the Sharing Study, while restricted to three villages, provides the richest data on mixed subsistence-cash economies available for rural communities in Alaska, and thus, offers an opportunity to understand the linkages between ecosystem service dependencies and participation in the cash economy.

Task SE2: Identify past trajectories and rates of change and likely future changes in critical ecosystem services.

Task SE2 builds on the NSF project “IPY: Impact of High-Latitude Climate Change on Ecosystem Services and Society” (0732758) which interviewed local
subsistence harvesters to document knowledge of how environmental conditions affect “availability” of resources (abundance + distribution and movements + access). Part of the research documented local observations and understandings of recent and long-term ecological change. Local knowledge of changing environmental conditions and their implications to subsistence harvesting were prepared in reports, which were reviewed by local residents for feedback. We also worked with staff at the University of Alaska Scenarios Network for Alaska Planning (SNAP) office to identify best available science and spatially explicit downscaled climate models to assess the implications of future climate change on village ecosystem services.

In the fall of 2012 we initiated a new research partnership with the community of Nenana, Alaska, located on the Parks Highway southwest of Fairbanks. Nenana (pop. 402 with 41% Alaska Natives is situated on the Tanana River and close to ecological study sites of the BNZ LTER. Because of its on-road location and mixed Native – non – Native population provides a contrast to previous LTER work we have done with the community of Venetie. At the request of community leaders, we initiated our research by interviewing 7 elders of the community to document oral life histories and local knowledge of changes in resources, landscapes, and human subsistence livelihood activities (i.e. hunting, fishing trapping, and time on the land). Interviews were semi-structured to accommodate the communication patterns of Native respondents and included a participatory mapping component to capture data spatially. All interviews were videotapes. Interview materials are now being coded to identify themes and videos are being edited, to eventually be posted on the BNZ website. Interviews (and participatory mapping methods) for active Nenana hunters and fishers are now being designed, and will be administered in the winter of 2013. Depending on the success of the interviews, we hope to use this approach to develop an on-going community-based ecological monitoring program in several communities of interior Alaska. As well, we have compiled imagery (BARR, Landsat, and Quickbird) for the Nenana area and historic photos of the landscape and town. We are using imagery to quantify land cover land use change – specifically focused on fire history and the human footprint (infrastructure). Historic photos matched with current photos will be also used to analyze landscape changes.

The methods developed for the above-mentioned research with Nenana are part of the on-going efforts of the Maps and Locals LTER (MALS) working group. The MALS working group requested funding for a workshop to be held in Boulder, Colorado Feb 22-25, 2013. That workshop will focus on the methods and challenges of integrating local knowledge and GIScience across the LTER Network. Funding was awarded by the LTER Network office and will have 20 participants from across the country. BNZ (Kofinas) serves as the lead for the MALS group and the workshop. The MALS group also met at the ASM of LTER to plan the workshop and develop plans to for a cross-site research proposal, which will be submitted in 2013.

Task SE3: Model the interaction of ecological, economic, cultural, and demographic conditions affecting participation in subsistence in rural households of interior Alaska, and how those dynamics affect village sustainability.
We built a prototype simulation model that represents social-ecological system dynamics of a rural Alaskan village. The model is based on household economic and subsistence data collected from the BOEM Study of Sharing Networks (mentioned above) and the “IPY: Impact of High-Latitude Climate Change on Ecosystem Services and Society” (0732758)

Task SE4: Conduct institutional analysis to identify the role of policy in mediating the effects of changing ecosystem services.

The work on institutional analysis is now being initiated. In particular we will focus on if and how local knowledge and science are represented in regional decision making processes, such as those of the Alaska Board of Game and issues of cumulative effects are being considered.

Task SE5: Through partnerships with communities, identify conditions that facilitate innovation in future human adaptation and transformation.

Nenana and other communities were engaged in a conversation about the research with the ultimate goal of completing task SE5. In some cases communities stated a strong preference to not focus on community adaptation or resilience, but instead to focus on community issues of self-reliance. Those discussions are on-going with plans to engage specific communities on that topic in further discussions. An NSF ARC SEES proposal was written and submitted (Chapin PI) that would fund this activity for Interior Alaska (as well as with coastal communities).
Training and Development:

Involvement in K-12 education (Schoolyard LTER): BNZ contributions to education and development of human resources extend beyond college and graduate education. Outreach to K-12 children through the Schoolyard LTER (SLTER) has brought hands-on experience in learning science through teacher training courses/workshops, classroom involvement by LTER scientists, engaging all students in a classroom in ongoing research or by mentoring some students in investigations that they have independently developed. The Schoolyard LTER has provided place-based, investigative scientific activity to schoolchildren in and around Fairbanks and has been particularly effective at involving Native Alaskan children and communities in science: We currently work with 10 Alaska Native high schools from rural Alaskan communities to engage them in LTER research. Specific programs are highlighted below.

Teacher Workshops: Teachers have implemented the research protocols and best teaching practices they learned during the professional development training workshops and implemented them in their classrooms in rural and urban schools in Alaska and other states. Student participation in GLOBE Seasons and Biomes/SLTER has included studies on ice seasonality (freeze-up and break-up), frost tube/active layer monitoring, plant phenology, weather and hydrology, collaborations with students in other schools, and contributing data through internet submissions to the GLOBE Data Archive for use in students’ and scientists’ research. Also, students have presented their findings at statewide science symposiums or at international conferences. Other teacher workshops have been conducted by Christa Mulder and Katie Spellman. These professional development workshops by Mulder, Spellman and Sparrow have been offered for credit as UAF natural resources management and/or education courses that teachers take for continuing education credits or for other teacher needs.

LTER scientist involvement with pre-college teachers and students: LTER scientists, including graduate students and staff, continue to work with K-12 teachers and students by giving presentations in classrooms, mentoring students in their science fair or high school science symposium research projects as well as serving as judges in local and regional Science Fairs and the Alaska Statewide High School Science Symposium (ASHSSS). Sparrow has continued to coordinate the Science Fair at a Fairbanks school. LTER graduate student Katie Spellman mentored a middle school student in a study of the desiccation tolerance of invasive aquatic plant, *Elodea canadensis*. The student placed first at the regional science fair and won several special honors, including a microscope.

Some LTER graduate students have worked closely with K-12 teachers in Fairbanks schools throughout the school year in a collaborative project called GK-12 Changing Alaska Science Education (CASE) program, sharing their science expertise with the teachers while learning how to communicate their science to diverse audiences by co-teaching in the classrooms. For example, graduate student Amanda Rinehart co-taught the day-to-day science activities in a 1st grade classroom, and brought the students to our research site at CPCRW for a fieldtrip, where they learned about forest fire and
vegetation succession, made charcoal artwork, and took measurements of stream velocity and water temperature. This project was featured on the local news. Two teachers that Katie Spellman has been working with in CASE, presented at the 2012 BNZ LTER Symposium, their students’ work and enthusiasm for the Ecologist in a Classroom project. One of the teachers is a long time GLOBE teacher and was using some of the GLOBE measurement protocols in stream monitoring.

An Alaskan Invasive Plant Species Curriculum Guide for K-6 students was developed and published by LTER graduate student Katie Spellman in collaboration with a SLTER teacher Christine Villano from Denali Elementary School. They have conducted several teacher workshops using the curriculum, to raise awareness and knowledge about Alaska invasive plants, and to engage students in research and eradication of invasive plants. One program this team led allowed educators and their students to contribute data to a phenology database, which has been used to validate the models being produced with historical data. They also published a paper 'Early Primary Invasion Scientists' in the Jan 2011 issue of Science and Children. As the Ecologist in Residence at North Pole Middle School, Spellman translated BNZ ecological research into dynamic inquiry lessons for 7th grade biology classrooms at North Pole Middle School. Katie writes and delivers lessons as a part of the NSF GK12 Fellowship in the 'Changing Alaska Science Education' program. She is also using this experience to evaluate whether there are differences in the effectiveness of two different educational methods in teaching middle school students to incorporate new knowledge: guided inquiry vs. a meta-cognitive approach. As a culminating experience for the 108 middle school students she worked with, all the students travelled to the UAF Kasitsna Bay Lab in Kachemak Bay Alaska for a week-long ecology immersion trip. BNZ LTER in collaboration with the GLOBE Seasons and Biomes funded the travel for underprivileged students who receive free and reduced-cost lunches, as well as for a teacher and a student chaperone.

Development of Master trainers/teacher leaders: Trained teachers have mentored and trained other teachers in scientific measurements for use in inquiries and research that their students conduct and share their implementation successes and best teaching practices for science, technology and mathematics education. GLOBE Seasons and Biomes/LTER Teachers in Alaska, California, Illinois, South Africa and Switzerland have trained other teachers in 2012 as well as the past two years.

International activities: SLTER has ongoing collaborations with GLOBE (worldwide long term environmental/earth science program with 112 partner countries) and Seasons and Biomes Project (an International Polar Year education outreach project) in providing professional development (PD) workshops for teachers, on earth system science concepts, scientific measurement protocols, best teaching practices and a model for student scientific investigation. These PD workshops have been conducted in Alaska, in other states and internationally. In October 2011, Seasons and Biomes helped conduct a PD workshop in Croatia for 85 educators from 24 participating schools (10 in Norway, 8 in Croatia and 6 in the Czech Republic), for a Tree Ring project. In November 2011, a PD workshop was conducted in Belgium for thirty educators, (mostly high school
teachers and a couple of elementary school teachers). In June 2012, a PD workshop at UAF was conducted by SLTER and Seasons and Biomes for 11 educators (teachers from North Pole, Anchorage, Dillingham, Seward, Kalskag, and Wasilla, a park ranger from the Kenai Fjords National Park who works with 3 school districts, the education outreach coordinator of Andrew Forest LTER in Oregon and two teachers from Illinois and Colorado). In July 2012, another PD workshop was conducted in Fairbanks for nine teachers. Seven teachers came from Beaver, St. Mary, Palmer, Valdez and Fairbanks, Alaska, one teacher from Illinois and the other from New Hampshire. The Fairbanks PD workshops also served as training grounds for early career scientists from UAF and the Univ. of Tennessee, to work with teachers.

REU Student Training: Each year, the BNZ LTER grant supports 2 undergraduate REU students. Senior Personnel interested in mentoring an REU student submit a 1-page proposal to the BNZ Exec Committee that includes a description of the project, including what (and with whom) the student will working on throughout the summer, and how it will provide a unique research experience for the student, and an explanation on how the research is tied to specific tasks outlined in our recent proposal. This year, students were mentored by labs supervised by Merritt Turetsky and Glenn Juday. Anna Lello-Smith (Turetsky’s lab), an undergraduate at Tufts University, was hired as a REU student to contribute to research examining the effects of permafrost thaw on ecosystem C balance. Anna was paired with a senior graduate student, who mentored her on research inquiry and hypothesis testing. As part of a one page proposal, Anna developed a hypothesis and methods to test that hypothesis, and received feedback from LTER scientists Hollingsworth, Turetsky, McGuire, and Harden. Anna was interested in gaining experience in plant ecology, and decided to quantify vegetation gradients in areas affected by permafrost thaw. Anna focused on patterns of moss succession in the BCEF collapse scar bogs. At the end of the summer, Anna presented her results to LTER scientists and McGuire’s lab group. While not publishable on their own, Anna’s data likely will lead to a coauthored paper and she has expressed interest in continuing a career in research. Ryan Jess (Juday’s lab), a UAF NRM undergraduate, was hired as the second REU student to assist in several long-term dendrochronology studies. Jess participated in all aspects of the research, and learned field, laboratory and statistical methods for linking long-term tree growth and climate change patterns. This included a 650 mile trip along the Tanana, Kantishna and Yukon rivers, collecting tree cores as part of a larger project examining broad regional responses of white and black spruce to climate variability and change in interior Alaska. Jess also sampled black spruce in 40-60 year old burn scars from a suite of sites that are now part of the BNZ LTER new site network. Jess was also involved with re-sampling of stands within a large forest health monitoring program, and helped with a new effort to sample tree growth patterns within lower interior Alaska along the Copper River. The REU experience has inspired Jess to pursue a career in science, and he has plans for continuing research in Juday’s lab towards going on to graduate school.

Involvement in graduate education: Graduate education is a major component of the BNZ LTER Program. Approximately 50 graduate students were affiliated, at some level, with BNZ research in 2011-2012. The Bonanza Creek LTER has been the central
natural science facility for an IGERT graduate program in Regional Resilience and Adaptation that links ecological, economic, and cultural aspects of sustainability and resilience.

**Direct involvement of under-represented groups in BNZ research:** The Bonanza Creek LTER program has contributed substantively to education and diversity at many levels and has made substantial progress toward the goal of broadening participation in science at all levels. Women scientists are well-represented at all levels of the BNZ LTER. Forty-one percent of the PIs and senior personnel involved in BNZ in 2012 are women. Of the LTER graduate students in our last grant period, 56% are women and 11% are minorities (Native American, Asian, and Hispanic/Latino). Our major effort to enhance diversity is through recruitment of minority graduate students, particularly Alaska Natives. Minority recruitment has been a strong emphasis of the IGERT graduate program in Resilience and Adaptation, which links ecological, economic, and cultural aspects of sustainability and resilience. The Bonanza Creek LTER is the central natural science facility for the Resilience and Adaptation program. There are over 40 graduate students in this program, many of whom are involved in LTER research. Research experience opportunities to undergraduate students have been provided by Bonanza LTER through the Research Experience for Undergraduate Program. Female and male, urban and rural, Native and non-Native students have participated in these research experience opportunities.

**Research Experience for Teachers:** Mr. Stephen Decina, inner-city middle school teacher from Newark, NJ, joined BNZ LTER during summer 2012 as a part of the research experience for teachers program. Decina joined Dr. Mulder’s research team investigating the impacts of non-native plant invasions on the pollination and fruit production of *Vaccinium* sp. The experience began with an orientation to the BNZ LTER research sites and conceptual and methodological training through a one credit 500-level professional development field course, taught by LTER PhD student Katie Spellman and SLTER teacher Christine Villano. Decina then fully participated in all Mulder Lab field and laboratory activities: plant phenology monitoring, community composition data collection, stigma collection and preservation methodologies, pollen identification and quantification, fruit and seed set calculation, pollinator observation, edaphic and light condition data collection. Decina then completed his own independent research project on the community-level phenology of native and invasive plants at the BNZ field sites. Under the guidance of Dr. Mulder and PhD student Katie Spellman, he gained experience collecting and analyzing his own ecological data, and presented his results at the LTER All Scientists Meeting in Estes Park, CO and at the Alaska Invasive Species Conference in Kodiak, AK. Decina will deliver professional development training to his teaching colleagues in Newark during Spring 2013 based on his RET experiences.

**Outreach Activities:**

Public outreach is an important component of Bonanza Creek activities. We regularly take diverse groups on visits to our LTER research sites at Bonanza Creek
Experimental Forest (BCEF) and Caribou-Poker Creeks Research Watershed (CPCRW), both as group efforts and as visits with individual investigators. We have established four demonstration sites at CPCRW and the APEX-peatland Demonstration Site that are specifically intended for education and outreach activities for students, scientists, and managers. The CPCRW sites cover a range of fire and vegetation conditions, making them well suited for long-term use in demonstrating the different post-fire successional trajectories that are possible in Alaskan black spruce forests.

Mulder and graduate student Katie Spellman took advantage of a wide range of public education programs to introduce people to the problems of invasive species and competition for pollinators in the context of a rapidly changing climate. Mulder attended the US Science and Technology Expo in Washington, DC, and introduced families to the taste of Alaska native berries and the importance of bumblebees and solitary bees for their fruit production. Mulder and Spellman attended three public outdoor education events in Anchorage (two at Potter’s March and one at the Botanical Garden). Additional public lectures were given at the Murie Science Center and the CES Master Gardener’s course. These events reached approx. 1200 people, primary families, and were used to recruit volunteers to the citizen science phenology monitoring program (see next paragraph).

Mulder and Spellman have developed, piloted (summer 2011) and fully launched (summer 2012) a statewide citizen science program to aid in their research on interactions between invasive plants, native berry plants and pollinators. Volunteer citizens monitor the phenology of focal species across the state. Mulder and Spellman conducted in-person volunteer trainings in Fairbanks and Anchorage, and conducted distance-delivery trainings via webinar for remote volunteers in small towns and villages across the state. In the first year of program implementation, 89 citizen scientists from families, youth groups, nature centers and tourist groups contributed 354 observations at 50 monitoring sites. Mulder and Spellman are using these data to determine the geographic mosaic of potential pollinator interactions between Melilotus albus and Vaccinium vitis-idaea and V. uliginosum based on phenological overlap of the native and invasive species. Data will supplement and validate models that predict phenology based on climate and geographical variables that are being developed using herbarium records; these models will be used to produce a risk model for the entire state of Alaska, with particular emphasis on rural communities that have not yet been invaded by Melilotus. All information on this network is available on the project website: https://sites.google.com/a/alaska.edu/melibee-project/.

Outreach to K-12 children through the Schoolyard LTER has brought hands-on experience and inquiry to children learning science through teacher training courses/workshops, classroom involvement by many LTER scientists, and engaging all students in a classroom in on-going research or by mentoring some students in investigations that they have independently developed. More details on these educational programs are provided in the Training, Development, and Mentoring section under Schoolyard LTER activities.
LTER scientists often present their research to a variety of community groups through classes, presentations, and workshops. PhD candidate Katie Spellman has been actively engaging community members, teachers, students, and land managers in LTER research through numerous activities and programs focusing on invasive plant ecology in Alaska. She also gave an Association of Polar Early Career Scientists career development seminar on best practices in developing citizen science research programs. The Osher Lifelong Learning program adult education provides another avenue for LTER scientists to share their research with community members. Recent courses in 2011-12 led by LTER scientists have covered the science of climate change, the role of humans in ecological change, energy and economics, predator-prey relationships, and more. Chapin partnered with an educator from the Arctic Consortium of the United States, worked with teachers in a Climate Change field based class they taught at the Denali National Park in the summer of 2012.

Schuur participated in the radiocarbon short course “Radiocarbon in Ecology and Earth System Science”, which was taught for the first time at Max Planck in Jena, Germany. The goal of this intensive course is to train the next generation of researchers in ecology and earth sciences in the use of AMS technology. Increased numbers of $\Delta^{14}C$ measurements combined with more researchers skilled in the interpretation of $\Delta^{14}C$ data offers great promise towards addressing the human impact on global carbon cycling and the feedback to climate change. This course was co-organized by Dr. Schuur and Dr. Susan Trumbore. For the 2012 class, we had ~20 graduate students and postdoctoral researchers from universities around the world that attended the full course (lab plus lecture), with a handful of other students and researchers at Max Planck attending the morning lectures. For much of this year, Schuur has still been organizing the class instructors to use the class materials to produce a short textbook about the use of radiocarbon in ecology and earth system science. Half of the draft chapters are now in, with the other half in the final stage before internal review. The book has 9 chapters covering the basics of the carbon cycle and the application of radiocarbon for understanding this cycle. We are planning to hold the next course in the summer of 2014 at UC Irvine.

Shuur hosted a teacher at the Healy research site in the late winter/spring period for the second year in a row. This was coordinated through the Polartrec program by Sue Natali. A middle school teacher (John Wood) from Orange County, CA spent time at the site and prepared materials for his classes based on his experience helping with the fieldwork.

Research at the Healy site continues to be used as a foundation for developing a protocol for the Denali National Park and Preserve as part of the Central Alaska Network of Parks. This protocol is being developed for long-term monitoring of carbon and permafrost. Additional work on the Standard Operating Protocols continued this year in close collaboration with park researchers (Dave Schirokauer). Finally, this site has been chosen as a relocatable site for the National Ecological Observation Network (NEON) taiga domain, and we continue to interface with that effort in particular trying to provide a bridge between science and the local community.
LTER scientists have also brought their ecological research to faith-based groups. At the 'One People, One Earth -- Faith and Stewardship Conference' (2011), graduate student Spellman, along with BNZ investigators Sparrow and Chapin, provided information to faith-based groups in the Fairbanks area on BNZ research. Spellman initiated an effort to parallel ESA's pilot speakers bureau program in Fairbanks, and provided information to conference participants on how to get an ecologist to come speak with their faith community. Chapin presented at the One People, One Earth Conference again in 2012. Investigator Juday served as Lead Scientist and Trainer for the Catholic Coalition on Climate Change to train Catholic Climate Ambassadors who are commissioned to present public programs and work with Catholic institutions to accurately present and interpret the science of climate change.

In a Time of Change (ITOC) - Arts and Humanities Program at BNZ

A network of visual and performing artists, writers and scientists has been actively working together since 2007 to integrate scientific and artistic perspectives on social-ecological issues in interior Alaska. To date, these efforts have involved field workshops for artists, writers and performers with scientists (2007, 2009, 2010, 2011, 2012), fostering collaborative creative processes that have culminated in public performing arts events (2008, 2010) and visual art exhibits presented locally, regionally and nationally (2010, 2012, 2013).

Our series of projects has generated considerable enthusiasm among artists, scientists and the public. It has created a growing consortium of Alaskan artists and scientists committed to 1) exchanging perspectives between the arts, sciences and humanities on topics related to social-ecological systems 2) producing high-quality, original work informed by these collaborations and 3) presenting these works to the public to promote awareness and understanding of science and the interactions between humans and the ecosystem.

Our local art exhibits and performances have been attended by >2,000 people in Fairbanks, with countless more people reached in our regional and national touring exhibits and workshops, LTER network-wide arts and humanities activities, and via our project websites, noted below.

In a Time of Change: The Art of Fire (2011-2012)
http://www.frames.gov/partner-sites/afsc/projects/art-of-fire/#.UOznMo6qYeA
In a Time of Change: The Art of Fire is a visual arts project designed to generate excitement, facilitate mutual understanding and promote meaningful dialogue on issues related to fire science and society. Interactions between artists, fire managers and scientists aimed to promote understanding and awareness of the scientific basis behind fire management practices in the context of Alaska's changing ecosystems. The project facilitates a sense of place, and to help promote public understanding of the functionality of fire in the ecosystems of Interior Alaska.

Nine local artists were invited to embrace the inspiration of wildfire, fire science and fire management through field workshops with fire scientists and fire managers. Artists then created original works for an art exhibit and offered public lectures and studio tours. The primary exhibit of professional art was presented free to the public at the Bear Gallery in Fairbanks during August 2012, and was attended by 742 people. A notably high level of attendance (450) was recorded at the Bear Gallery opening reception. A secondary exhibit of contributed art works by fire scientists and managers was also presented at the Alaska Public Lands Information Office at the Morris Thompson Cultural Center in Fairbanks simultaneously. Local media outlets, including newspaper, radio and television featured the project prominently in their coverage, reaching countless more audience members. Photos of the exhibit and audio/visual recordings of lectures by artists and scientists are on the project website, as well as videos of local television news coverage.

We collected survey data from attendees, with the option of completing hard copies (brochure inserts) or using a smart phone, with the opportunity to enter a drawing for original art pieces as incentive. The response was quite positive, for example, 71% of 141 respondents agreed or strongly agreed with the following: “After viewing the Art of Fire show, I am motivated to learn more about fire science, fire management, and wildfire protection in Alaska”, and 96% of 131 respondents agreed or strongly agreed with the following: “I believe that art can be an effective mechanism for building public awareness and understanding of important issues”.

Selected pieces from The Art of Fire. Clockwise from top left: fiber art by Rae Nancarrow, painting by Jessie Hedden, photograph by Amanda Ellis, painting by Jennifer Moss.
Selected works are now on a touring exhibit to Alaska Pacific University in Anchorage, AK (Jan. 4-29, 2013), and several will likely be included in an upcoming (2013) exhibit at the National Science Foundation Headquarters in Virginia.

Several invited platform presentations have been presented at conferences on *ITOC: The Art of Fire* by BNZ ITOC Director MB Leigh and by AFSC Director Sarah Trainor. Presentations by Leigh and Trainor were made at a meeting entitled *Words on Fire: Toward a New Language of Wildland Fire* in Corvallis, OR (Nov. 1-2. 2012), and Trainor presented at the Alaska Fire Science Consortium Annual Workshop (Oct. 12, 2012) in Fairbanks, AK. The Art of Fire project has also been featured in many workshops and presentations by Leigh as part of LTER Network-wide activities detailed below. This project was funded by BNZ in partnership with the U.S. DOI Joint Fire Science Program and was developed by BNZ personnel (Leigh) with substantial support from the Alaska Fire Science Consortium (AFSC).

*In a Time of Change: Trophic Cascades (2012-2013)*

A new ITOC program is currently underway at BNZ in collaboration with Denali National Park and Preserve, entitled *In a Time of Change: Trophic Cascades*. Ten artists from across Alaska were selected through a competitive proposal process, and visual artists representing diverse styles and media, as well as prose writers, playwrights and an Alaska Native storyteller were selected. The theme of the project focuses on the dynamics of predator/prey interactions and associated effects on the ecosystem via trophic cascade effects, including the effects of humans and predator control on ecosystems. Two field workshops were offered to artists along with scientists, one in Denali National Park (2.5-day) and Bonanza Creek LTER (1-day). In-kind support for this project was provided by Denali National Park and Preserve and the Murie Science and Learning Center. The project will culminate in an integrated, multimedia gallery exhibit in August of 2013 in Fairbanks, AK. Opportunities for state and national touring of the exhibit are actively being sought.
Leadership and Participation in Network-wide Arts and Humanities Activities

BNZ has been a leader in LTER Network-wide arts and humanities activities. ITOC Program Director Mary Beth Leigh (BNZ) co-leads the *Ecological Reflections* program ([www.ecologicalreflections.com](http://www.ecologicalreflections.com)) along with leaders of arts and humanities activities from AND (Fred Swanson), NTL (Terry Daulton) and HFR (Clarisse Hart). Ecological Reflections is a network of sites dedicated to long-term, collaborative science and art inquiry into particular sites of great ecological or cultural importance. Leigh has helped coordinate and expand the national network of ecological research sites involved in arts and humanities activities and to bring the artistic products to a nationwide audience through touring art exhibits, workshops, conference presentations, and the Ecological Reflections website.

Leigh has lead or co-lead several workshops to facilitate the establishment or enhancement of arts/humanities activities by LTER and other ecological research sites, museums and other institutions. Leigh has lead workshops at the Ecological Society of America (Portland, OR, Aug. 2012) and LTER ASM (Estes Park, CO, Sept. 2012), and also delivered an invited platform presentation at The American Geophysical Union (San Francisco, Dec., 2011). These activities have resulted in the formation of new arts/humanities programs and an expansion of the Ecological Reflections network.

With Ecological Reflections, Leigh co-organized a touring art exhibit featuring selected works from BNZ, AND, HFR and NTL was mounted at National Science Foundation Headquarters (Virginia, Feb.-June 2012), where it reached numerous scientists, foundation affiliates and policymakers, with support from NSF. A subset of the exhibit then was mounted at the ESA Annual Meeting (Portland, OR, Aug. 2012), where over 400 attendees visited the Ecological Reflections booth adjacent to the LTER Network Booth. The art exhibit and information were very enthusiastically received by attendees, and stimulated a great deal of interest and productive discussion. Several art pieces were exhibited at the LTER ASM in Estes Park, CO (Sept. 2012), and another exhibit is planned for Oregon State University (Feb. 2013) before the works return to their home sites.

Ecological Reflections leaders, including Leigh, are now preparing a manuscript for peer-reviewed publication. Leigh is Co-PI on a newly awarded an LTER Cross-site synthesis postdoctoral synthesis award, and will work to document and synthesize arts and humanities activities across the LTER Network.
### Outside Funding:

<table>
<thead>
<tr>
<th>Title</th>
<th>PI, co-Pis</th>
<th>Dates</th>
<th>Amount</th>
<th>Source</th>
<th>Nature of BNZ LTER Support</th>
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<tbody>
<tr>
<td>Warming and Drying Effects on Tundra Carbon Balance</td>
<td>Natali, Schuur</td>
<td>2012-2015</td>
<td>$598,000</td>
<td>NSF OPP</td>
<td>LTER logistics; LTER infrastructure</td>
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<td>Effects of Warming the Deep Soil and Permafrost on Ecosystem Carbon Balance in Alaskan Tundra</td>
<td>Schuur, Luo</td>
<td>2011-2014</td>
<td>$1,024,000</td>
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<tr>
<td>Identifying Indicators of State Change and Forecasting Future Vulnerability of Alaskan Boreal Ecosystems</td>
<td>Schuur, Mack, Johnstone, McGuire, Euskirchen, Rupp</td>
<td>2011-2016</td>
<td>$2,477,000</td>
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<tr>
<td>From Community Structure to Functions: Metagenomics-Enabled Predictive Understanding of Temperature Sensitivity of Soil Carbon Decomposition to Climate Warming</td>
<td>Zhou, Konstantinidis, Luo, Tiedje, Schuur</td>
<td>2011-2016</td>
<td>~$2,000,000</td>
<td>DOE Microbes</td>
<td>LTER logistics; LTER infrastructure</td>
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<td>Vulnerability of Permafrost Carbon Research Coordination Network</td>
<td>Schuur, McGuire</td>
<td>2010-2014</td>
<td>$401,974</td>
<td>NSF RCN</td>
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<td>Project Title</td>
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<td>Years</td>
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<td>DISSECTATION RESEARCH: Carbon Cycle Changes in a Changing Climate: Using $^{13}$C and $^{14}$C to Partition Ecosystem Respiration in Tundra Undergoing Permafrost Thaw</td>
<td>Schuur, Hicks Pries</td>
<td>2010-2011</td>
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<td>Development and Application of an Integrated Ecosystem Model for Alaska</td>
<td>McGuire, Rupp, Euskirchen, Romanovsky, Marchenko</td>
<td>2011-2016</td>
<td>$1,439,751</td>
<td>USGS and USF&amp;WS</td>
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<tr>
<td>Identifying indicators of state change and forecasting future vulnerability in Alaskan boreal ecosystems</td>
<td>UAF: McGuire, Rupp, Euskirchen (note that there are U. Florida and U. Saskatchewan components)</td>
<td>2011-2016</td>
<td>$1,017,766 UAF Component</td>
<td>Dept. of Defense</td>
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<td>Research Coordination Network: Vulnerability of Permafrost Carbon</td>
<td>Schuur, McGuire</td>
<td>2010-2014</td>
<td>$401,487</td>
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<td>Soil climate and its control on wetland carbon balance in interior boreal Alaska: Experimental manipulation of thermal and moisture regimes</td>
<td>Turetsky, McGuire, Harden</td>
<td>2007-2013</td>
<td>$285,000</td>
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<td>Partitioning of soil respiration along moisture gradients in Alaskan Landscapes</td>
<td>McGuire</td>
<td>2009-2012</td>
<td>$122,087</td>
<td>USGS</td>
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<td>Integrated Ecosystem Model for Alaska</td>
<td>Rupp, McGuire, Euskirchen, Romanovsky, Marchenko</td>
<td>2010-2011</td>
<td>$409,999 total project (PI Rupp)</td>
<td>USF&amp;WS</td>
<td>long-term BNZ LTER data; LTER logistics; LTER infrastructure</td>
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<td>Assessing the Impacts of Fire and Insect Disturbance on the Terrestrial Carbon Budgets of Forested Areas in Canada, Alaska, and the Western United States</td>
<td>McGuire</td>
<td>2008-2011</td>
<td>$254,000</td>
<td>Dept. of Agriculture</td>
<td>long-term BNZ LTER data; LTER logistics; LTER infrastructure</td>
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<td>Assessing the role of deep soil carbon in interior Alaska: Data, models, and spatial/temporal dynamics</td>
<td>McGuire, Harden</td>
<td>2008-2011</td>
<td>$246,128</td>
<td>USGS</td>
<td>long-term BNZ LTER data; LTER logistics; LTER infrastructure</td>
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<td>Boreal Alaska - Learning, Adaptation, Production (BAK LAP)</td>
<td>Juday, Grant, Dawe</td>
<td>2012-2014</td>
<td>$1,000,000</td>
<td>Alaska DNR</td>
<td>long-term BNZ LTER data and plots; LTER infrastructure</td>
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<td>2011 Yukon River Basin Studies – Floodplain Longitudinal Transect of Climate Sensitivity across Alaska</td>
<td>Juday</td>
<td>2010-2012</td>
<td>$99,000</td>
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<td>2010 Yukon River Basin Studies – Large Forest Plot Monitoring Data Collection and Analysis and Tree Ring Data Bases for NDVI Comparison</td>
<td>Juday</td>
<td>2010-2011</td>
<td>$124,115</td>
<td>USGS</td>
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<td>Monitoring Seasons Through Global Learning Communities (also called Seasons and Biomes)</td>
<td>Sparrow, Verbyla, et.al</td>
<td>2006-2013</td>
<td>$1,584,580</td>
<td>NSF</td>
<td>infrastructure, teacher support</td>
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<td>COLLABORATIVE RESEARCH: Spatial and Temporal Influences of Thermokarst Failures on Surface Processes in Arctic Landscapes</td>
<td>Jones, Gens, Jorgenson, Kofinas, Sparrow</td>
<td>2008-2013</td>
<td>1,444,296</td>
<td>NSF</td>
<td>infrastructure, teacher support</td>
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<td>Project Description</td>
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<td>Dangerous Ice: Human perspectives on changing winter conditions in Alaska</td>
<td>Kielland, Schneider</td>
<td>2009 - 2013</td>
<td>$359,264</td>
<td>NSF</td>
<td>long-term BNZ LTER data; LTER logistics; LTER infrastructure</td>
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<td>Interactions of Fire and Thermokarst Affecting Ecological Change In Alaska</td>
<td>Kielland</td>
<td>2011-216</td>
<td>$379,470</td>
<td>USGS</td>
<td>long-term BNZ LTER data; LTER logistics; LTER infrastructure</td>
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<td>Nutritional Ecology of snowshoe hares</td>
<td>Kielland</td>
<td>2010-2014</td>
<td>$11,179</td>
<td>NPS</td>
<td>long-term BNZ LTER data; LTER logistics</td>
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<td>Dietary analysis of furbearers in interior Alaska based on stable isotope analysis</td>
<td>Kielland</td>
<td>2011-2013</td>
<td>$10,000</td>
<td>ADF&amp;G</td>
<td>long-term BNZ LTER data</td>
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<td>Collaborative Research: Stream Consumers and Lotic Ecosystem Rates (SCALER): Scaling from Centimeters to Continents</td>
<td>Jones, Harms</td>
<td>2011 - 2016</td>
<td>$335,042</td>
<td>NSF</td>
<td>long-term BNZ LTER data; LTER logistics; LTER infrastructure</td>
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<td>Spatial and Temporal Influences of Thermokarst Failures on Surface Processes in Arctic Landscapes</td>
<td>Jones, Gens, Jorgenson, Kofinas, Sparrow</td>
<td>2008 - 2013</td>
<td>$1,444,296</td>
<td>NSF</td>
<td>long-term BNZ LTER data; LTER logistics</td>
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<td>IPY: A community Genomics Investigation of Fungal Adaptation to Cold</td>
<td>Taylor</td>
<td>2007-2012</td>
<td>$743,697</td>
<td>NSF</td>
<td>long-term BNZ LTER data; LTER logistics; LTER infrastructure</td>
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<td>State of the Arctic Report</td>
<td>Romanovsky</td>
<td>2005-2012</td>
<td>$80,000</td>
<td>NOAA</td>
<td>long-term BNZ LTER data analysis</td>
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<td>Development and application of an integrated ecosystem model for Alaska</td>
<td>Rupp, McGuire, Romanovsky</td>
<td>2011-2013</td>
<td>$3,911,826</td>
<td>FWS, USGS</td>
<td>long-term BNZ LTER data analysis and modeling</td>
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<td>Project</td>
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<td>Funding (USD)</td>
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<td>Ecology, Soil Carbon, and Permafrost Experiments (ECOSCAPE)</td>
<td>Waldrop, Euskirchen</td>
<td>2011-2013</td>
<td>~200k/yr</td>
<td>USGS Climate Science Center</td>
<td>long-term BNZ LTER data; LTER logistics; LTER infrastructure</td>
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<td>Fate of Carbon in Soil Systems (FOCSSY)</td>
<td>Waldrop, Harden</td>
<td>2009-2014</td>
<td>~500k/yr</td>
<td>USGS Research &amp; Development</td>
<td>long-term BNZ LTER data; LTER logistics; LTER infrastructure</td>
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<td>Metagenomics of Permafrost Soil Microbiota-Implications for Climate Change</td>
<td>Waldrop</td>
<td>2010-current</td>
<td>paid for services and</td>
<td>Joint Genome Institute, DOE</td>
<td>long-term BNZ LTER data; LTER logistics; LTER infrastructure</td>
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<td>Microbiomics of complex communities in environmental samples</td>
<td>Janet Jansson</td>
<td>2007-1010</td>
<td>250k/yr</td>
<td>DOD LDRD</td>
<td>long-term BNZ LTER data; LTER logistics; LTER infrastructure</td>
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<td>Differences in spatial diversity and biogeography of N-cycling microbial communities due to habitat characteristics across continental scales</td>
<td>Dorthe Petersen</td>
<td>2009</td>
<td>100,000 $ (tax free travel grant)</td>
<td>Carlsbergfoundation</td>
<td>long-term BNZ LTER data; LTER logistics; LTER infrastructure</td>
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<td>Resilience, resistance, and vulnerability of boreal forests to environmental change</td>
<td>Johnstone</td>
<td>2012-2017</td>
<td>$105,000</td>
<td>NSERC</td>
<td>Canadian student participation in LTER research; LTER logistics</td>
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<td>Microbial detoxification of petroleum-contaminated soils</td>
<td>Leigh</td>
<td>2011-2012</td>
<td>50,000</td>
<td>NIH (Alaska INBRE)</td>
<td>long-term BNZ LTER data; LTER logistics; LTER infrastructure</td>
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<td>Detoxification of petroleum in Alaskan terrestrial and marine environments</td>
<td>Leigh</td>
<td>2012-2013</td>
<td>25,000</td>
<td>NIH (Alaska INBRE)</td>
<td>long-term BNZ LTER data; LTER logistics; LTER infrastructure</td>
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<td>Project Description</td>
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<td>Year(s)</td>
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<td>Supporting Activities</td>
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<td>Promoting collaboration between the arts and fire management in Alaska</td>
<td>Trainor, Leigh</td>
<td>2011-2012</td>
<td>25,000</td>
<td>U.S Department of the Interior, Joint Fire Sciences Program</td>
<td>LTER logistics; LTER infrastructure</td>
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<td>Restoration of remote contaminated soils through plant-microbe interactions.</td>
<td>Leigh, Taylor, Schnabel</td>
<td>2012</td>
<td>20,000</td>
<td>NSF (Alaska EPSCoR)</td>
<td>LTER logistics; LTER infrastructure</td>
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<td>Ecosystem level consequences of mutualist partner choice in alder across a forest successional sequence in interior Alaska</td>
<td>Ruess, Taylor, Kielland</td>
<td>2007-2012</td>
<td>$796,227</td>
<td>NSF</td>
<td>LTER logistics; LTER infrastructure</td>
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<td>The study of sharing to assess the vulnerability of communities to oil and gas development in arctic Alaska.</td>
<td>Kofinas</td>
<td>2008-present</td>
<td>$750,000</td>
<td>NSF</td>
<td>LTER logistics; LTER infrastructure</td>
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<td>IGERT – Resilience and Adaptation Program</td>
<td>Kofinas</td>
<td>2007-present</td>
<td>$3,200,000</td>
<td>NSF</td>
<td>LTER logistics; LTER infrastructure</td>
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<td>Impacts High Latitude Climate Change</td>
<td>Chapin</td>
<td>2007-present</td>
<td>$1,200,000</td>
<td>NSF</td>
<td>LTER logistics; LTER infrastructure</td>
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<td>Modeling harvesting behavior to understand adaptation, mitigation, and transformation in northern subsistence systems</td>
<td>Kofinas</td>
<td>2009-present</td>
<td>$316,779</td>
<td>NSF</td>
<td>LTER logistics; LTER infrastructure</td>
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<td>EPSCoR IV: Alaska Adapting to Changing Environments (Northern Test Case - NTC)</td>
<td>Meyers (Kofinas lead for NTC)</td>
<td>2012-present</td>
<td>$20,000,000; $1,700,000 for NTC component</td>
<td>NSF</td>
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