Annual Report for Period: 02/2011 - 01/2012
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

Name: Ruess, Roger
Worked for more than 160 Hours: Yes
Contribution to Project: BNZ LTER PI and lead of research on floodplain disturbance and succession

Name: Jones, Jeremy
Worked for more than 160 Hours: Yes
Contribution to Project: Leads work focusing on permafrost thaw and watershed hydrology and nutrient fluxes

Name: Mack, Michelle
Worked for more than 160 Hours: Yes
Contribution to Project: Heads research on post-fire biogeochemistry

Name: McGuire, A. David
Worked for more than 160 Hours: Yes
Contribution to Project: Leads synthesis modeling efforts focused on large-scale ecosystem dynamics and climate feedback pathways; supervisor of the BNZ data manager

Name: Hanley, Thomas
Worked for more than 160 Hours: Yes
Contribution to Project: Liaison with the US Forest Service, and contributes to research on herbivory and succession. Formerly Co-PI, currently senior personnel.

Name: Sparrow, Elena
Worked for more than 160 Hours: Yes
Contribution to Project: BNZ Education and Schoolyard LTER Coordinator

Name: Schuur, Edward
Worked for more than 160 Hours: Yes
Contribution to Project: Leads the research on interactions between permafrost thaw and altered ecosystem carbon budgets

Name: Johnstone, Jill
Worked for more than 160 Hours: No
Contribution to Project: Leads research on post-fire successional trajectories (Tasks D3/D4); formerly LTER PhD student studying plant ecology

Name: Verbyla, David
Name: Lloyd, Andrea  
**Worked for more than 160 Hours:** Yes  
**Contribution to Project:**  
Uses remotely sensed time series to determine trends in productivity (Task C1)

Name: Valentine, David  
**Worked for more than 160 Hours:** Yes  
**Contribution to Project:**  
Leads paleoecological research

Name: Euskirchen, Eugenie  
**Worked for more than 160 Hours:** No  
**Contribution to Project:**  
Studies soil carbon and nutrient dynamics, particularly as a function of changing moisture

Name: Harden, Jennifer  
**Worked for more than 160 Hours:** Yes  
**Contribution to Project:**  
Co-lead on the regional ecosystem dynamics and climate feedbacks section of this LTER grant

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:** No  
**Contribution to Project:**  
Studies evolutionary ecology of insect-plant interactions

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 plant 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

**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)

**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: 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: Walker, Xanthe
**Worked for more than 160 Hours:** No
**Contribution to Project:**
Conducted research on climate-growth relationships and resilience in northern black spruce forests (Task C1, D3)

Name: Frey, Matthew
**Worked for more than 160 Hours:** No
**Contribution to Project:**
Conducted research on controls of post-fire vegetation (Task D2)

Name: Tissier, Emily  
**Worked for more than 160 Hours:** No  
**Contribution to Project:**  
Assisted with research on the effects of fire regimes on successional trajectories (Task D3)

Name: Shenoy, Aditi  
**Worked for more than 160 Hours:** No  
**Contribution to Project:**  
Conducted research on the effects of fire regimes on successional trajectories (Task D3)

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:
PhD student researcher studying vulnerability to changing seasonality and modeling SES dynamics
Name: de Roo, Colette
Worked for more than 160 Hours: Yes

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: Guboroski, 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: Crummer, Grace

Technician, Programmer

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

Worked for more than 160 Hours: Yes
Contribution to Project:
LTER lab manager and research technician; formerly LTER MS student studying plant ecology
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: seasonal research technician for Forest Inventory and Analysis program
Name: Downing, Jason

Worked for more than 160 Hours: Yes
Contribution to Project: BNZ LTER Data Manager
Name: Charry, Bertrand

Worked for more than 160 Hours: No
Contribution to Project: Assisted with research on post-fire successional trajectories (Task D3)
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: Forest Soils Laboratory supervisor
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: Adema, Guy

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: Fastie, Chris

Worked for more than 160 Hours: Yes
Contribution to Project:
Affiliate scientist, paleoecological research
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, Syndonia

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: Connor, Betty
Worked for more than 160 Hours: No

Contribution to Project:
Affiliate scientist

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: Manies, Kirsten

Worked for more than 160 Hours: No  
Contribution to Project: Affiliate scientist, fire effects on soil carbon

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
Affiliate scientist, ecosystem studies, former post-doc

Name: Waldrop, Mark
**Worked for more than 160 Hours:** No
**Contribution to Project:** Affiliate scientist, soil science

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

Research Experience for Undergraduates

Name: Webb, Elizabeth
Worked for more than 160 Hours: Yes
Contribution to Project:
Worked in the field during the summer and fall of 2011 as part of the REU program. Applied to continue a master's degree at UF in 2012. Research activities supported in part by this grant.

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

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
Academic home for Johnstone and students; development of collaborative research between Canada and US

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

Other Collaborators or Contacts

Activities and Findings

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

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

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 on-going 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 their, other students' and other scientists' research. Also, students have presented their findings at statewide science symposiums or at international conferences.

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). Kielland mentored one high school student for the ASHSSS, who conducted a project on secondary metabolites in birch and willow?two major forage plants for moose and snowshoe hares (2010-2011). The student finished 2nd in the State wide competition and attended the national competition in San Diego. Former LTER graduate student and current LTER staff Dana Nossov mentored a high school student who was interested in the long term effects of fire on moose forage for her ASHSSS project. The high school student analyzed LTER’s long term vegetation dataset to complement her own field-based research on post-fire succession and moose forage, and presented her research to the public (2010-2011). Sparrow has continued to coordinate Science Fair at a Fairbanks school. 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 Teaching Alaskans Sharing Knowledge 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 (2011), 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.

An Alaskan Invasive Plant Species Curriculum Guide for K-6 students was developed and published by LTER graduate student Katie Villano 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.

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 and math education.

International Polar Year (IPY) and international activities: GLOBE and Seasons and Biomes Project (an IPY education outreach project) are ongoing collaborations with SLTER that has provided professional development workshops for teachers in Alaska, in other states and internationally.

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. 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. 41% of the PIs and senior personnel involved in BNZ in 2011 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.

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.

In 2011, Juday led a 2-day class and field trip to Bonanza Creek LTER, as part of a one-month experience for 20 undergraduate and high school students, half from Ohacha Mexico and half from rural Alaska, for the class Ecology and People of the Arctic. The Mexican students were in the 1st or 2nd year of university studies in a mixture of majors including biological sciences and 2-yr forestry technical programs for management of village communal forest lands in Oaxaca. The Alaska students were a mix of North Slope Inuit and Interior Athabaskan high school students with an interest in possible science or environmental careers. PhD candidate Amanda Rinehart, through the GK-12 Teaching Alaskans Sharing Knowledge program, co-taught the day-to-day science activities in a 1st grade classroom throughout the year (2010-2011) and brought her students to our research site at CPCRW for a fieldtrip, where they learned about fire and vegetation succession, made charcoal artwork, and took measurements of stream velocity and water temperature. This educational field trip was featured on local news.

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 worked with a committee of graduate students and staff to conduct a workshop aimed at helping researchers more effectively implement their outreach program plans. The Osher Lifelong Learning program adult education provides another avenue for LTER scientists to share their research with community members. Recent courses in 2011 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.

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. 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.

A network of visual and performing artists, writers and scientists has been actively working together since 2007 to integrate scientific and artistic perspectives on climate change in interior Alaska. To date, these efforts have involved field workshops (Summers 2007, 2009, 2010, 2011) and collaborative creative processes culminating in public performances (2008, 2010) and a visual art exhibit (2010). Most recently, a performance featuring original theatre, dance, readings and music was presented concurrently with an art exhibit event featuring original works by 24 Alaskan visual artists. This multimedia event was entitled In a Time of Change: Envisioning the Future. We estimate that the art exhibits and performances have reached approximately 1,000 people who have attended the events, and additional people via the Bonanza Creek LTER website (http://www.lter.uaf.edu/outreach/bnz_Collaboration.cfm).

Our series of projects has generated considerable enthusiasm among the artists and students involved, and between the public and participating scientists. It has created a growing consortium of Alaskan artists and scientists committed to 1) exchanging perspectives from the arts, sciences and humanities on future climate change scenarios 2) producing original work informed by these collaborations and 3) presenting these works to the public to promote awareness and understanding of the environmental issues facing Alaska.

Visual art from In a Time of Change: Envisioning the Future as well as pieces from 2 other LTER sites with arts programs will be touring in 2012 to 1) The National Science Foundation Building in Washington, D.C. (March 2012) 2) the Ecological Society of America Meeting in Portland, OR (August 2012) and 3) Portland International Airport (Jan-June 2013).

We have recently been awarded a 2-year grant from the Joint Fire Sciences Program and the Alaska Fire Sciences Consortium for a new iteration, entitled In a Time of Change: The Art of Fire. This program is now underway, and included a series of field workshops for 9 visual artists in summer 2011, and will result in production of a touring art exhibit, as well as amateur fire education graphic arts competition and other activities in 2012.
Planning is now underway for the 2012-13 ITOC program in collaboration with Denali National Park and Preserve, entitled In a Time of Change: Trophic Cascades. This project will focus on the dynamics of predator/prey interactions, and will include field workshops for artists with scientists in Denali National Park and Bonanza Creek LTER. The outcomes will include an integrated, multimedia touring exhibit.

Interest in engaging arts/humanities with long-term research programs for purposes of both primary inquiry and outreach has grown dramatically within the LTER network. Organization of Biological Field Station sites, and US Forest Service experimental forests. This broader network is known as Ecological Reflections (http://www.ecologicalreflections.com). The visual arts, performance, environmental ethics and history, and creative writing have all found expression in these place-based, long-view programs. Our program has actively participated in workshops at the LTER ASM meeting in 2009 and Andrews Experimental Forest in 2011, and we have proposed and been invited to conduct new workshops and sessions at the Ecological Society of America in 2012 and LTER ASM in 2012 to help new sites establish arts and humanities outreach programs.

LTER scientists, students, and staff regularly work with journalists and television reporters to convey the importance of LTER research to the public. LTER work with the Permafrost Carbon Network that predicts large scale permafrost thaw has recently received national attention through a Nature comment article, and subsequent reports on NBC and in newspapers (2011). LTER research is frequently featured in newspapers (e.g., New York Times, Anchorage and Fairbanks papers), popular magazines such as National Geographic, and on television.

**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,


Belshe; Schuur, E.A.G.; Bolker, B.M.; Brocho, R.; "Incorporating spatial heterogeneity created by permafrost thaw into a landscape carbon estimate", Journal of Geophysical Research - Biogeosciences, p. , vol. , (2012). Accepted,


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


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

**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 3m 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 Precipitation Weighing Bucket Measurements
55) Caribou-Poker Creeks Research Watershed: Hourly Snow Depth Measurements
56) Caribou-Poker Creeks Research Watershed: Hourly Snow Pillow Measurements
57) Caribou-Poker Creeks Research Watershed: Hourly Soil Moisture at varying depths
58) Caribou-Poker Creeks Research Watershed: Hourly Soil Temperature at varying depths from 1988 to Present
59) Caribou-Poker Creeks Research Watershed: Hourly Wind Speed and Direction from 1988 to Present
60) Caribou-Poker Creeks Research Watershed: Vapor Pressure Measurements: Hourly Data
61) Chugach National Forest Beetle Population Counts
62) Cooperative Alaska Forest Inventory
Densities of snowshoe hares at Bonanza Creek Experimental Forest

Fireline surface level and thaw depths: Wickersham fire sites (1977 - 2009)

Greenup values for interior alaska 1976 - Present

Ground Water Depth Readings at BCEF/LTER Floodplain Sites, 1991-Present: Hourly

Ground Water Depth Readings at BCEF/LTER Floodplain Sites, 1991-Present: Weekly

Hectares of Alaskan Forested Ecosystems Infested by Phytophagous and Phloeophagous Insects, 1955-2008

Height and DBH measurements of Lodgepole Pine Plantations in Alaska: 1984 - 2004

Litter Trap Results at the Tanana River Exclosures: 2001 - Present

Litterfall and Hare Pellet Summary at Bonanza Creek LTER Control Plots (1985 - Present)

Litterfall Weights From LTER Study Site Treatment Plots: 1990 - Present

Log Decomposition Dynamics in Interior Alaska 1 - Site Data

Log Decomposition Dynamics in Interior Alaska 2a - Log Data

Log Decomposition Dynamics in Interior Alaska 2b - Log Sampling Schedule

Log Decomposition Dynamics in Interior Alaska 3 - Disk Data

Log Decomposition Dynamics in Interior Alaska 4 - Nutrient Data

Log Decomposition Dynamics in Interior Alaska 5a - Preliminary Results (treatment down) - Absolute

Log Decomposition Dynamics in Interior Alaska 5b - Preliminary Results (treatment down) - Retained

Long Term Tree Growth Sites: Hourly Temperature and Hourly Relative Humidity at 150 cm from 1988 to Present

LTER treatment plot circumference growth: 1989 - Present

National Atmospheric Deposition Program (NADP): Concentration Data, 1992 - Present

National Atmospheric Deposition Program (NADP): Seasonal Wet Depositions Totals (kg/ha), 1992 - Present

NRCS Snow Survey Data

Photosynthetically active radiation (PAR) data from APEX Fen, 2005 - 2006

Rain, well and river water oxygen and deuterium isotope analyses/values for Bonanza Creek Experimental Forest and LTTG sites (2002 - Present)

Snowshoe hare pellet count data in Bonanza Creek Experimental Forest

Snowshoe hare physical data in Bonanza Creek Experimental Forest: 1999-Present

Soil Moisture (TDR) Measurements at LTER Moisture Exclusion Treatment Plots: 1994-Present (weekly)

Soil Moisture (TDR), Temperature, and Precipitation Measurements at FP3A Moisture Exclusion Treatment Plots: 2002-Present

Soil Moisture (VWC) at LTER Moisture Manipulation Treatments

Soil Temperature at LTER Moisture Manipulation Treatments

Soil Temperature measurements at Long Term Tree Growth Sites; 1989-Present: Hourly

Soil Temperature Measurements at LTER Floodplain Successional Sites (FP1A,FP2A,FP4A): 1985-present (hourly)

Spruce Seedling Data Bonanza Creek Experimental Forest Floodplain Inside and Outside of the Moose Exclosures

Stream water chemistry of CPCRW, 2002- 2007

Summer Throughfall Precipitation Recorded at LTER Moisture Exclusion Treatment Plots: 1991-Present (weekly)

Sun Photometer - NASA Aerosol Robotic Network

The impact of permafrost thaw on ecosystem carbon balance: Carbon fluxes in a tussock tundra under permafrost thaw.


The impact of permafrost thaw on ecosystem carbon balance: net ecosystem exchange of a heterogenous landscape undergoing permafrost thaw

The impact of warming on ecosystem carbon balance: Half-hourly soil moisture and temperature data from the CiPEHR project, Healy AK, 2008-2009

Tree band growth data taken at BCEF sites (1989 -Present)

Tree Growth data taken at LTTG sites, 1969-Present: Reported Yearly

Tree inventory data taken at BCEF sites (1989-Present)

Tree stand structure summary at Bonanza Creek Experimental Forest LTER sites

Vegetation Plots of the Bonanza Creek LTER Control Plots: Species Count (1975 - 2004)

Vegetation Plots of the Bonanza Creek LTER Control Plots: Species Percent Cover (1975 - 2009)

Water table level data from APEX Fen plots, 2005-2006

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) Chemisty 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 the attached PDF for our contributions within discipline.

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:**

Contributions to Resources for Research and Education:

Direct contributions to education are described in the previous section. In addition to those direct contributions, however, the BCEF and the Caribou-Poker Creeks Watershed Research Area provide a widely used educational resource for the community. Both have been used by professors and their students in college level courses for biology and non-biology majors. This includes field courses taught in Alaska by educators from University of Alaska 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 other science education programs and have 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 have collaborated on other ecological projects and worked 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 and FY12 has been cut substantially, and there is considerable uncertainty about the sustainability of USFS funding for the BNZ LTER (see more detail in Participants). In addition, the USFS supports 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/), and has been training BNZ LTER graduate students and co-serving as the USFS representative to the BNZ LTER for the past several years. 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 intimately 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; Hanley and Hollingsworth, Forest Service communication; Jones, permafrost/hydrology, Mack, vegetation/fire disturbance; McGuire, data management and modeling.

3. The LTER executive committee (leadership team plus Hollingsworth, Yarie, site manager, data manager, and student representative) 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 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 are expanding our monitoring program to include a new regional network of black spruce sites that more closely match our evolving focus on resiliency and mechanisms of landscape change. These sites will be positioned within 3 interior Alaska ecosystems on land owned by the State of Alaska and Bureau of Land Management where we are currently working, and when necessary research permits are being obtained.

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). 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 moved into the role of affiliate LTER investigator, and we anticipate close interactions with him and his research program after his retirement. 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.

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
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. A Penguin Computing Altus 2100 computer running Windows Server 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 Windows Server hosts the 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 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. There is also one Dell Power Edge 2500 server running Windows XP Professional that hosts our Exabyte Tape backup system for workstations. These primary servers, and key workstations, are backed up on external drives and tape drives, as well as with the University of Alaska Fairbanks Arctic Region Supercomputing Center.

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 CFM scripts; allowing users to query, view and download metadata and data. These features provide a more interactive and productive web experience when looking 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 metadata for each of our 381 datasets, most of which have a higher level of completeness (levels 3-5), which is generated with a Perl script and a XSLT style sheet transformation.

The BNZ data catalog currently contains 381 distinct data packages. Of that, 111 of these data packages are ongoing and being routinely updated. During the last year we have added 20 new completed data packages from investigators, research associates, or students and we continue to see additional submissions on a regular basis. Additionally, we are continuing with outreach efforts involving investigators and students to ensure our data catalog remains as current and complete as possible.

Datasets in the Bonanza Creek 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 weekly harvests of our database 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. Our LTER has also contributed data to the LTER Trends project and continues to evaluate how we can improve this collaboration. We will be participating in the Veg-DB workshop at Harvard Forest this summer. 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 7,000 unique visitors and about 260,000 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 is available in real time; facilitated by a radio network and internet connection linking our field data loggers to the relational database.

Network Data Management Activities:

*IMEXEC (http://im.lternet.edu/home/imexec)

In September of 2011, at the annual IMC meeting in Santa Barbara California, BNZ Information Manager Jason Downing was elected to a three year term 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.

* Data Package Manager Tiger Team
Jason Downing has been participating over the past year with the NIS development Data Package Manager (DPM) tiger team. This tiger team was tasked to provide input and use case testing for the management software that allows for data packages to be created, updated, read, or deleted.

*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, and the EML Quality WG while Jamie Hollingsworth continued to be a play an integral role with the GIS WG.

*NIS Product Oriented Working Groups (http://im.lternet.edu/projects/NISProposals)

-LTERmapS Project
BNZ Site Manager Jamie Hollingsworth has continued to play a lead role with the continuation of the LTERmapS project. This project was awarded funding for a meeting to take place at the LNO office to complete the pilot project for LTERmapS Phase 2 and develop a strategy for expanding the application to all LTER sites.

-Interactive Cartographic Almanac
Jamie Hollingsworth was awarded funding from the LNO as part of their IM buyout time program for the completion and implementation of an Interactive Cartographic Almanac. The GIS working group was asked to develop an easily accessible and useful dynamic mapping tool for non-GIS experts that could be used to create content driven maps for presentations or publication inserts.

-ECC Requirements Workshop
Jason Downing co-authored a NIS product oriented working group proposal to have site information managers work with NIS developers at the LNO to define checks to ensure the high quality submitted data packages. This project has been funded and is moving forward in sync with the NIS development schedule and is coordinating its efforts with Data Quality Manager (DQM) tiger team.

*Supplemental Funding 2011
In 2011, BNZ was awarded supplemental funding to further enhance our information management activities in preparation for the upcoming release of the NIS. This influx is being used to participate in two network wide efforts to prepare data for the developing NIS. The first involves defining best practices and standards for integrating real-time sensor network data (SensorNIS); while the other tackles the handling of geographic and remote sensing data (GeoNIS). Each project includes funding to participate in a corresponding workshop and to provide for some additional technician time to implement these initiatives.

Contributions Beyond Science and Engineering:

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 Kielland 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

I. 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 CO₂ 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 turn 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 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. 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 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.

A major goal of the program is to 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 by establishing a new network of long-term research sites across young (0-10 yr), intermediate (40-60 yr) and mature stands (>80 yr). This was initiated during 2011 by first creating vegetation maps of a number of intermediate-aged fire scars. These maps were based on a supervised classification of Landsat imagery, and depicted various canopy composition and cover. From these maps, we were able to pick sites that were easily accessible, as well as covering a wide range of compositional variability. Figure 1 depicts one of the maps created for the Wickersham Dome Fire (1971). Sites are labeled on the map, and vegetation classes are depicted in various colors.

Figure 1. Landsat classification of the Wickersham Dome fire scar. The fire scar is depicted as a red line. New network sites are labeled and span mixed deciduous/coniferous (yellow), pure deciduous (bright green), and various densities of predominately spruce (brown and tan).

Sites encompassed a large range in variability in stand density and proportion of conifers to deciduous trees in the canopy (Figure 2). However, we also saw that individual fire scars exhibited striking patterns in stand density. For example, the Murphy Dome fire scar, on average, had higher absolute density than the Gerstle River
fire scar, likely due to a variations in the interactive effects of fire severity, parent material, recruitment dynamics, herbivory, and time since fire.

Figure 2. Variability in canopy composition across all fire scars as a proportion of conifers to deciduous (based on Basal Area). Sites with 100% conifers have a proportion of 1.0, and sites with 100% deciduous have a proportion of 0.0

Figure 3. Average age of stands when they burned separated by fire scar. Data were taken from standing dead burned trees that were remaining on sites post fire. There was a significant difference in the ages of stands burned of each fire scar.
We also examined the age structure and recruitment dynamics of all 30 sites visited. We found that each fire scar averaged a different age when burned, ranging from 70-142 years old, which could contribute strongly to the post-fire stand structure (Figure 3). One of the most surprising preliminary results was evidence for recruitment of all species up to 15-20 years after the fire burned (Figure 4). These results could be due to community factors such as herbivory, or population factors such as seed source and seed rain. This is interesting in light of previous evidence suggesting that community composition is determined within 10 years post-fire, and suggests that even if composition is determined immediately post-fire, factors influencing stand structure are more dynamic and ongoing throughout succession than previously thought.
A component of our research is to determine trends in productivity from a longer temporal and larger spatial perspective based on tree-ring measurements and historic satellite data. Preliminary findings show that aspen growth is negatively correlated with temperature at all sites, regardless of topographic position (Figure 5). For aspen on both Bonanza Bluff and nearby UP2C (an upland site that is presumably less moisture-stressed than the bluff), growth was significantly and inversely correlated with temperature in the months preceding the growing season—particularly late winter.

The response of aspen ring-width to precipitation is more mixed. Aspen at Bonanza Bluff responded favorably to early winter (October through January) precipitation, but grew more slowly in years when July precipitation was high. Aspen
growth at UP2C, in contrast, was not significantly correlated with any precipitation variable.

![Figure 5](image_url)

**Figure 5.** Correlation of aspen ring-widths on Bonanza Bluff (LEFT) and at UP2C (RIGHT) with temperature and precipitation. The y-axis is the correlation coefficient; error bars are the 95% confidence intervals (estimated by bootstrapping). Black bars are those in which confidence intervals do not overlap with zero.

The floodplain white spruce sample contains a stable common signal representing a strong negative relationship between summer temperature and tree growth. We developed a floodplain temperature index (FPTI), which explains half the variability of the composite chronology, and a supplemental precipitation index (SPI) based on correlation of monthly precipitation with the residual of the temperature-based prediction of growth. We then combined FPTI and SPI into a climate favorability index (CFI), in which above-normal precipitation partially compensates for temperature-induced drought reduction of growth and vice versa. CFI and growth have been particularly low since 1969. Our results provide a basis for building longer chronologies based on archeological wood and for projecting future growth.

Our recent analysis shows that BCEF and CPCRW had declining 1986-2009 NDVI trends similar to those reported from regional remote sensing studies. Although BCEF and CPCRW had similar declining NDVI trends, the mean unburned NDVI at BCEF was significantly greater that at CPCRW, presumably due to higher productivity at BCEF. Disturbed areas such as the 1983 Rosy Creek Burn, the 2001 Survey Line Burn, and the 2004 Boundary Burn had significant post-fire increases in NDVI, while wetland classes had no significant trends. There were large (>10 ha) forest patches of declining NDVI at both BCEF and CPCRW, with patches occurring within both spruce and broadleaf forest classes and on upland, floodplain, and lowland landscapes. The 1986-2009 declining trend was similar among all forest classes and may be due to a
regional climate regime shift since the mid-1970s. We found white spruce and mixed forest in the floodplain had stronger declining NDVI trends relative to uplands, which may reflect a greater sensitivity to climate. The NDVI response following the 2004 drought was the largest decline from the NDVI trend line for all forest classes except black spruce. The post-drought decline in mean NDVI was significantly greater for the cooler and moister CPCRW area compared to the BCEF area, perhaps due to shallow soils at CPCRW relative to much deeper loess soils at BCEF.

We have recently completed set-up of a new experiment to manipulate the amount and seasonal timing of soil moisture availability, in order to assess influences on productivity of dominant coniferous species. Preliminary findings indicate that snow melt elimination had no affect on aboveground tree growth. This finding is based on only three years of data on the upland sites and two years of findings on the floodplain sites. A preliminary explanation for the lack of differences could be tied to the relatively low winter snowfall in the past two years (2009-2010 and 2010-2011). We do not yet have estimates of TBCF for any of the experimental plots. Partitioning soil respiration into autotrophic and heterotrophic components using $^{14}$C makes use of the relatively enriched $^{14}$C in soil organic matter resulting from the $^{14}$C spike associated with a period of atmospheric thermonuclear weapons testing that terminated in the early 1960s. As a result, heterotrophic respiration is expected to be relatively enriched in $^{14}$CO$_2$ compared to autotrophic respiration. Using this approach, we obtained total soil respiration $\Delta^{14}$C values that were higher than we obtained for heterotrophic respiration in surface (0-20 cm) soils alone. Assuming no methodological errors this implies a large contribution of heterotrophically-respired CO$_2$ from deeper in the soil profile, undermining the common assumption that activity in boreal soils is largely restricted to surface layers.

A significant effort in this section is to document the effects of climate variability, vegetation type, and predation on vertebrate herbivore abundance along a latitudinal boreal transect. Hare populations on our Spruce Grid and Riparian Grid along the Tanana River floodplain continue to exhibit the same seasonal patterns as have been observed the last three years. The population on the Spruce grid maintains a fairly high spring population and a moderate increase over the summer. By contrast, the Riparian population has exhibited a large (6-fold) increase between spring and fall population densities. We believe this is largely due to emigration from the study grid in late winter and immigration to the grid during green-up. During 2011, we had 209 capture events involving 145 individual snowshoe hares (below). Population densities ranged from a low of <0.6 hares/ha in the spring to 3.5 hares/ha in the fall. As noted we believe the extraordinary population increase on the Riparian grid was largely due to immigration during the summer, rather than exceptional rate of recruitment.

Since our snowshoe hare mortality study began in 2008, we have collared and followed the fate of approximately 300 individuals. Hares on the Spruce grid tend to survive at a greater rate than hares associated with riparian habitats, but since June 2010-May 2011 the cumulative rates of mortality have been fairly constant on both grids (Figure 6). Survival typically is higher in the summer than winter, and we typically observe an increase in mortality at the onset of winter (Sept-Nov) and during the first breeding season (April). Survival was high during summer 2011 but went into a
precipitous decline in late September (Figure 7). This trend has continued until present. Predation accounts for approximately 90% of all documented hare mortality. The source of this mortality is biased towards lynx in the spruce habitats and goshawks in the more open riparian habitats.

Table 1. Total number of capture events, estimated populations size and population densities of snowshoe hares 2011.

<table>
<thead>
<tr>
<th></th>
<th># total caught</th>
<th># hares</th>
<th>Pop size</th>
<th>Hares/ha (± S.E)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spruce grid</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spring 2011</td>
<td>70</td>
<td>29</td>
<td>33</td>
<td>1.3 (0.4)</td>
</tr>
<tr>
<td>Fall 2011</td>
<td>41</td>
<td>28</td>
<td>42</td>
<td>1.9 (0.6)</td>
</tr>
<tr>
<td>Willow grid</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spring 2011</td>
<td>17</td>
<td>6</td>
<td>6</td>
<td>0.6 (0.1)</td>
</tr>
<tr>
<td>Fall 2011</td>
<td>81</td>
<td>43</td>
<td>64</td>
<td>3.5 (0.9)</td>
</tr>
</tbody>
</table>

Figure 6. Cumulative Kaplan-Meier survival estimates based on telemetry and staggered design of snowshoe hares occupying spruce forests and riparian shrub communities in Bonanza Creek Experimental Forest 2010 – 2011. Annual survival ranged from approximately 25% - 35% on the Spruce grid and Riparian grid, respectively.
We recently completed an experiment to determine whether intake of soil aids hares in digesting plant secondary metabolites (PSM). Below we illustrate the effects of these interactions from a trial with willow leaves during summer 2011.

Snowshoe hares fed forage with PSM (largely tannins, in the case of felt-leaf willow) and with access to mineral soil exhibited approximately 25% higher food intake than hares without access to mineral soil (Figure 8). The rate of willow consumption was statistically insignificant from hares fed the control diet (“D”-ration, a pelleted diet with
the same energy and protein content as leaves, but without PSM). Moreover, hares fed the control diet exhibited no change in intake in relation to access to mineral soil. Hares fed the D-ration maintained body weight during the feeding trial and access to mineral soil had no effect on body weight. By contrast, hares fed willow leaves in the absence of mineral soil showed a significant drop in body weight compared to hares that could (and did) consume mineral soil. Complete composition analysis of soil and forage samples are forthcoming and will be reported at a later date.

Five male and 5 female were caught in the BNZ study area between late January and early December 2011, ranging in body weight from 7.0-12.6 kg. None of the females were accompanied by kittens. Three lynx were subsequently recaptured; 2 males and a 1 female. Two of the animals recaptured in cage traps were released without handling, and 1 male caught in a foot snare was anesthetized and his collar replaced. All lynx responded well to anesthesia (Telazol™, 3mg/kg).

Location data of lynx in BNZ continue to show extensive use of ecotonal habitats. Individuals appear to occupy core areas of approximately 100 km². Lynx also show considerable variation in straight-line daily movement rates, but typically range from 5 – 10 km/day. We are currently analyzing the effects of collar transmission schedule on the estimated rates of movement, and we also plan to track lynx in the field to estimate the correction factor for travel rates obtained from GPS collars. Map shows monthly locations for a male lynx in BNZ Experimental Forest Jan-Aug 2011. There appears to be rapid turnover of the lynx population in the study area. We estimate we have collared 25-50% of the population in the fall, but all of our collared lynx have died within a year of being collared. All documented 19 mortalities so far have been due to fur trapping.

Another component of our research on direct effects climate variability and change on ecosystems and disturbance regimes is to 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. During the beginning of the 2000s, permafrost temperatures within
Alaskan Interior were relatively stable with little noticeable increase. During the last three to four years, even some decrease (from 0.1°C to 0.3°C) in permafrost temperatures was observed in the region around Fairbanks (Figure 9). This decrease is likely due to relatively low snow cover thickness after the mid-1990s in this region.

![Figure 9](image)

**Figure 9.** Time series of annual permafrost temperatures measured from south to north across the Interior Alaska and Alaska and Brooks Ranges.

Results of our numerical modeling of ground temperature dynamics for four different ecotypes typical for the Fairbanks region are shown in Figures 10 and 11. Our calculations show that the increase in air temperature projected by a mid-range A1B climate scenario for the Fairbanks region during the next 90 years, sooner or later will trigger permafrost degradation within all ecotypes in this region, except for the tussock tundra found at some locations small valley bottoms around Fairbanks.
Figure 10. Projections of ground temperature changes in the upper 15 m that may occur as a result of changes in air temp (a) for two types of black spruce forest with thick organic layer, (b) with relatively dry moss surface (upper-right photo), and (c) with wet moss surface (bottom-right photo).

Figure 11. Projections of ground temp changes in the upper 10 m below the ground surface that may occur as a result of changes in air temp (A) in the valley bottoms in Fairbanks area for two ecotypes: B – tussock tundra, and C – mixed shrub.
An important goal of the program is to 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 a first attempt at disentangling a signal of aspen leaf miners in aspen ring-widths, we compared ring-width patterns of aspen at Bonanza Bluff and UP2C with the record of ALM outbreaks (using archived LTER data from S. Werner). Two aspects of the ring widths were considered. First, we looked for periods of reduced growth: these occur relatively frequently in the aspen ring-width series (Figure 12), and tend to be coincident at the two sites. Second, we identified “white rings” in the tree cores. White rings are bright, white rings that have been identified as indicators of defoliation events in aspen, although they have primarily been used to identify tent caterpillar outbreaks they may be useful in identifying ALM outbreaks. We found repeated white rings at UP2C, but not at Bonanza Bluff. White rings were associated with three of four periods of substantially reduced growth at UP2C (Figure 12), and may thus indicate that defoliation events are reflected in the ring-width record.

The temporal correspondence between periods of growth reduction in aspen and acreage of ALM outbreaks was relatively weak. An outbreak in the 1970s, for example, is associated with an extended period of reduced growth at Bonanza Bluff, but not at UP2C. The most recent outbreak has not been reflected in particularly depressed growth at either site. More localized, site-specific data on outbreak history of these particular stands will be useful in further interpreting the ring-width record of outbreaks. At this point, the chronology of white rings—which seem to be a more specific indicator of defoliation than growth reductions—may be the most effective tool for reconstructing outbreaks. In 2012, we will re-examine a large number of aspen cross-sections collected several years ago by Dan Mann and Scott Rupp as part of a Joint Fire Sciences Project in order to develop region-wide white ring chronologies for aspen.
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.

Johnstone et al. (2011) reported that model simulations with ALFRESCO indicate that under scenarios where high levels of surface fire severity led to increased dominance by deciduous forest, landscape flammability and the number of large fire events decreased. Under scenarios dominated by low surface fire severity, larger patches of contiguous conifer forest promoted fire spread and resulted in landscapes with shorter fire return intervals compared to scenarios of high surface severity. Nevertheless, these negative feedbacks between fire severity, deciduous forest cover, and landscape flammability were unable to fully compensate for greater fire activity under scenarios of severe climate warming. Model simulations suggest that the effects of climate warming on fire activity in Alaska’s boreal forests may be partially but not completely mitigated by changes in fire severity that alter landscape patterns of forest composition and subsequent fire behavior.

Kasischke et al. (2012) found that in Alaskan black spruce forests, there was little difference in the depth of burning under trees compared to away from trees. This result is in contrast to Boby et al (2010), who found 15% deeper burning under black spruce trees than in randomly located points. The differences in these conclusions have not been resolved. We also found that during the 2000s, 14% of the mature black spruce stands experienced the deep burning (e.g., where residual organic layer depth < 3 cm) required for a shift to post-fire dominance by deciduous tree species, while 25% of the stands had organic layer depths between 3 and 10 cm, where increased recruitment of deciduous species might be expected (Barrett et al. 2011). This research is being led by Kirsten Barrett as part of her research as a USGS Mendenhall Fellow.

Preliminary results from Hewitt’s work indicate that fire severity does not influence richness of ectomycorrhizal fungal (EMF) communities on resprouting shrubs (Figure 13a), and that most species of tree seedlings have overlapping EMF with adjacent resprouting shrubs (Figure 13b) suggesting that later successional fungi may be maintained on the roots of the shrubs after lower severity fire.
Figure 13 a,b: Left: Average OTU richness for *Betula nana* resprouts across the Anaktuvuk burn; right: Seedling that established in burned areas with <3 cm of remaining organic after fire had a low number of shared ECM with nurse shrubs (p=0.0699, $F^* = 3.3921$)

Taylor and Bent’s work on EMF communities associated with alder, aspen, spruce and birch four years after a stand-replacing fire at CPCRW yielded the following findings (Bent et al. 2011). First, EMF found on root tips were diverse (71 phylotypes),

Figure 14: Result of an NMS ordination where fungal root tip community data from seedlings of the same species are pooled for each of the 3 sampling areas around each focal alder. Different plant species are represented by different symbols: down triangle=aspen, up triangle=birch, square=spruce, circle=alder. Note that the alder communities are distinct from those of the other 3 plant species.
with no evidence for spatial structuring (i.e. patchiness) across the site, suggesting either that diverse propagules survive in the deeper layers of soil, or that dispersal and recolonization are relatively rapid. Second, the communities were dominated by various ascomycetes and 'weedy' basidiomycetes that are typical of highly disturbed habitats, and quite distinct from those found in mature forests. Third, there was a large amount of overlap in fungal taxa associated with aspen, birch and spruce (suggesting the possibility of mycorrhizal networks), but not with alder, which had a very distinct community (Figure 14). Fourth, certain fungal taxa were correlated with faster or slower growth of seedlings, suggesting potential impacts of fungal species composition on the ensuing competitive dynamics of these regenerating plant taxa.

Mulder and Spellman's preliminary work on the effects of an invasive N-fixer on pollination success of native species suggests that, overall, conspecific pollen loads on Vacciniums were lower on the stigmas located 8-20 m away from the outplanted Melilotus in experimental plots than in control plots, and similar both immediately adjacent to the Melilotus and >25 m from the Melilotus. Similarly, they found high loads of Melilotus pollen in the first two orbits, and low loads in the third and fourth orbits. These data suggest that pollinators are attracted to Melilotus and pollinate berry plants located adjacent to these, but that pollinators are drawn away from berry plants located at intermediate distances from the flowering invasives. Preliminary results for fruit set supported these conclusions, with higher fruit at experimental sites immediately adjacent to outplanted Melilotus, but lower fruit set at intermediate distances. Although they do not yet have climate data incorporated into their models of flowering time for the different species, preliminary analyses for V. vitis-idaea suggest later flowering as latitude increases but also much more rapid development, primarily at latitudes >64 °N.

Initial observations of seedlings that recruited following the 2004 fires indicate that many sites are supporting higher rates of tree growth than 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. We are also considering future analyses using tree-rings to compare early tree growth between past and currently developing stands, to investigate whether changing climate-growth relationships may account for some of the unexpectedly high rates of tree productivity observed.

We have recently shown that C and N emissions from tundra fires were approximately 60% of those from boreal black spruce forests (Boby et al. 2010, Mack et al. 2011) despite large differences in aboveground biomass pools. Pre-fire soil organic layer element pool sizes were similar between systems and combustion of soil organic matter contributed 70% of element emissions in both. Boreal fires, however, burned substantially deeper: the average depth of burning in boreal black spruce forests during the 2004 fire season was 16.7 cm; depth of burning in the Anaktuvuk River Fire averaged 7 cm. However, the bulk density of the organic layer was substantially higher in tundra than in boreal soils, probably due to the high contribution of carbon-dense sphagnum and sedge detritus in tundra versus less dense feather moss detritus in boreal forest.
Alexander et al (in review) reported that aboveground biomass, ANPP, and deciduous snag biomass increased significantly with increased deciduous importance value (IV) and time since fire across the suite of intermediated-aged boreal forest stands. Deciduous IV did not influence evergreen snag biomass or downed woody debris, but both C pools decreased with time since fire. To assess how stand composition influences C pools, they subdivided stands into five forest types based on relative contribution of different tree and large shrub species to total stand biomass. Black spruce stands had shorter trees with less basal area and AG biomass and slower rates of biomass accumulation and ANPP compared to trembling aspen (*Populus tremuloides*) and Alaskan paper birch (*Betula neoalaskana*) stands. If an intensifying boreal fire regime leads to a shift in stand composition from predominantly black spruce to increased deciduous dominance, ANPP, aboveground biomass of trees and large shrubs, and deciduous snag biomass will increase, leading to increased aboveground C pools and productivity in mid-successional forest stands of interior Alaska.

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

An important component of this research is to 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. Results of our calculations show that most areas with mean annual ground temperatures below 0°C at 1 m depth are concentrated in the central and eastern part of the basin. Present-day temperatures of permafrost vary from near 0°C in the central and western part of the region to -5°C and colder in the foothills and mountains in the northern and southern parts of the region (Figure 15, top right). By 2099, mean annual temperatures at 1 m depth will stay below 0°C only in these mountain parts (Figure 15, bottom right). Figure 15 also shows that including the effect of wild fires using outputs from ALFRESCO/DOS-TEM for vegetation and organic layer characteristics in the GIPL-1 model produces significant changes in ground temperatures and permafrost distribution for the time periods 2000-2009 and 2040-2049 (compare left and right plots in the top and middle of Figure 15). As expected, ground temperatures are warmer and permafrost extend is smaller when the effect of fires is taken into account. At the same time, the difference between these two runs is much smaller for the 2090-2099 time period (Figure 15, bottom left and bottom right).

The DOS-TEM simulations indicate that the active layer depth of surviving shallow permafrost increases across the AKYRB from about 1 m to about 1.5 m by
Figure 15. Mean annual ground temperatures at 1 m depth for control run (left) and including effect of forest fire on organic layer and vegetation (right) averaged for (top) 2000-2009, (middle) 2040-2049, and (bottom) 2090-2099 using CCCMA climate forcing.
2040 in the CCCMA simulation, and to about 1.7 m by 2020 in the ECHAM5 simulation in association with fire activity in the early part of the 21st Century. After reaching a maximum depth, the average active layer depth above the surviving permafrost will then return to approximately its late 20th Century depth by end of the 21st Century as organic horizons recover from the increased fire activity early in the century, and the extent of permafrost will decrease significantly particularly in those regions where the active layer depth is especially thick during the 2040s. This is illustrated by the results of the active layer depth calculations performed using GIPL-1 model (Figure 16). This figure shows the active layer (or the seasonally-thawed layer above the permafrost) depth in blue and in yellow-red for the depth of the seasonally-frozen layer in permafrost-free areas or in the areas where the permafrost table is located at some depth below the seasonally-frozen layer (area of closed taliks). Analysis of these results shows that in the areas of deep active layer in 2040-2049 (Figure 16, middle right), the further climate warming of the second part of the current century resulted in thawing of the upper part of permafrost and in a shift from seasonally thawed layer to seasonally frozen layer (Figure 16, bottom right). At the same time, the depth of the active layer above the surviving permafrost has not changed significantly (compare Figure 16, top right and bottom right).

Table 2. Comparison of areas occupied by MAGT below and above 0C at 1 m depth and mean annual ground temperature at the same depth over the AKYRB region using the CCCMA climate forcing.

<table>
<thead>
<tr>
<th>GIPL Model Run</th>
<th>Year</th>
<th>Area, sq. km</th>
<th>% from the Total AKYRB Area</th>
<th>Soil Temperature Over AKYRB, deg C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>AKYRB Total</td>
<td>MAGT &lt;=0</td>
<td>MAGT &gt; 0</td>
</tr>
<tr>
<td>Ctrl Fire</td>
<td>2000-2009</td>
<td>526,484</td>
<td>385,509</td>
<td>140,975</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>328,789</td>
<td>197,695</td>
</tr>
<tr>
<td>Ctrl Fire</td>
<td>2040-2049</td>
<td>218,270</td>
<td>218,270</td>
<td>308,214</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>187,523</td>
<td>338,961</td>
</tr>
<tr>
<td>Ctrl Fire</td>
<td>2090-2099</td>
<td>82,275</td>
<td>82,275</td>
<td>444,209</td>
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<td></td>
<td></td>
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<td>76,728</td>
<td>449,756</td>
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</table>
Figure 16. Active layer thickness (meters): control run (left) and with including effect of forest fire on organic layer and vegetation (right) averaged for (top) 2000-2009, (middle) 2040-2049, and (bottom) 2090-2099 using CCCMA climate forcing.

Comparison of active layer thicknesses between the control run (Figure 16, left) and where fire-induced changes in surface vegetation and organic layer properties were
taken into account (Figure 16, right) shows significant increases of both the active layer and the seasonally-frozen layer thicknesses after fire. The increase in the seasonally-frozen layer thickness as a result of fire may also lead to colder winter temperatures in the upper meter of soil and to a slower rate of the organic matter decomposition in the mineral soil.

Comparison between the areas with MAGT below and above 0 C at 1 m depth in the control run (Ctrl) and in the run where fire affects surface vegetation and organic layer were taken into account (Fire) shows significant reduction of permafrost distribution. The percentage of permafrost compared to the total area of the AKYRB region decreased significantly after the fire (Table 2). During the current century, there is also a gradual increase in MAGT over the AKYRB and in areas occupied by soils with mean annual temperature above 0 C at 1 m depth for both control run and after the fire.

We are also examining 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, and have found that 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 the low permafrost watershed, residence time increased as discharge increased above 30 L/s. The mechanism to explain this pattern is unclear, but may be related to lateral storage related to stream channel morphological features such as root systems, mosses, and cut backs in the stream banks. We found no relationship between hydrologic residence time and DOC uptake in streams, indicating microbial uptake of carbon does not depend on contact time of microbes with substrate but may be limited by some other factor such as phosphorous. Whereas carbon uptake was not related to discharge, uptake was greatest in the stream draining the low permafrost watershed compared to the high permafrost watershed. Our evaluation of surface-groundwater interactions in riparian zones using an end-member model indicates riparian zone water is a mixture of shallow soil water with high DOC concentration and deeper ground water with lower DOC concentration. When thaw depth is shallow the soil water fraction is more important than the ground water fraction.

Net uptake of ammonium (NH$_4^+$) varied substantially across seasons (Figure 17), but lower net uptake rate in summer, when plants are actively growing, suggests that NH$_4^+$ uptake is balanced with mineralization. Net nitrate (NO$_3^-$) uptake declined sharply from snowmelt to summer, whereas peak denitrification 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 inorganic N to streams.
Our snow-fence experiment is examining the effect of natural and manipulated permafrost thaw on vegetation structure, and ecosystem C and N cycling in upland boreal tundra landscapes. The experimental warming manipulation 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. One of the initial findings is that soil temperatures were 4-8 deg 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 during warming persisted for an entire season. This pattern was repeated in the second 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 (Natali et al. 2011). Initially it appears that summer warming had the largest effect on carbon fluxes. Net ecosystem exchange (NEE) during the growing season was higher in the summer warming treatment as compared to the winter warming and control treatments, which did not differ. This increase net uptake was a result of higher gross primary productivity (GPP) and higher ecosystem respiration ($R_{eco}$), with uptake stimulated more than loss in the summer warming treatment. Despite increases in thaw depth, the winter warming treatment did not have higher respiration than control; this may have been a result of the water table that kept the deep soil saturated late in the growing season when the thaw depths were at maximum. In the second year of warming, the pattern differed – winter warming now had a big effect on GPP and $R_{eco}$ along with the summer warming effect that was observed the year before. Interestingly, the warming treatments all stimulated GPP more than $R_{eco}$ such that the treatments stimulated the sink capacity of the ecosystem. This matched our prediction based on a natural permafrost thaw gradient where initially the warming effect on plants was greater than on soil processes.
such that increased losses were offset by uptake. We submitted a second manuscript on this project focused on the response of the plant community to the direct and indirect effects of warming, now in press in the Journal of Ecology.

Fire triggers permafrost thaw beneath black spruce forests, and we continue to broaden our understanding of the associated patterns and mechanisms of soil C balance across chronosequences in interior Alaska (Delta Junction, Harden et al. 2006; Tok, Harden et al. in press; Hess Creek, O’Donnell et al. 2009), and Canada (Thompson, Manitoba, Goulden et al. 2011). While site to site variations in C stocks exist among stand ages, there is a pervasive, consistent response of C re-accumulation of approximately 20 to 40 gC/m2/yr across all of the study areas and stand ages. The net sink for C involves dynamics of both near-surface and deeper soils. Near-surface C sequestration is related to inputs by moss and litter during successional changes, whereas the dynamics of deeper soils are more poorly constrained. As sources for dissolved loads to surface waters, soils of these study areas likely release carbon, nitrogen, and nutrients in early stages of recovery from disturbance.

Data from the eddy covariance towers after the first year of measurements (2010–2011) indicate that the permafrost plateau is a CO2 sink of approximately 60 g C m\(^{-2}\) yr\(^{-1}\), while the young thermokarst bog is a source of CO2 of 64 g C m\(^{-2}\) yr\(^{-1}\). Permafrost thaw causes large changes in plant species composition, with a 60% decrease in gamma species diversity relative to the permafrost plateau. Permafrost thaw in this forested peatland reduced total aboveground biomass by 30% and decreased vascular aboveground net primary productivity by almost 70%. However, the thermokarst bogs had greater moss productivity than the permafrost peat plateau, resulting in no significant change in total aboveground productivity with thaw in this system. Between the two thermokarst bogs, more recent permafrost thaw was associated with greater aboveground biomass and a higher total NPP than the older thermokarst bog. Moss primary productivity also was higher in the newer thermokarst bog relative to the older bog. Together, these results suggest that permafrost thaw in poorly drained environments triggers carbon releases to the atmosphere primarily through soil C losses, and that enhanced plant productivity after thaw partially compensates for these ecosystem losses.

*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.*

Much of the research in this section is relatively new; therefore, we have few findings to report. With regards to the stem canker infection (*Valsa melanodiscus*) on *Alnus tenuifolia* (Ruess et al. 2009), our most survey shows that disease spread is resulting in continued alder stem density decline, particularly in young dense alder stands. It appears that alder may be eliminated from some stands, particularly in south-central Alaska, such as along the Eagle River near Anchorage. There is serious concern that invasion by the European bird cherry (*Prunus padus*), which is not an N-fixer and has very different green leaf and litter chemistry, will alter in-stream
decomposition processes, which may affect growth of juvenile salmon. We have begun collaborations with fisheries scientists to study these consequences.

In 2011, we retreated a willow-removal experiment initiated in 2009 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. The sites are approximately 100 miles up-river from the Yukon River bridge near the village of Beaver. 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. Fluvial processes, particularly large, nearly annual, spring-time sedimentation events appear to distinguish early successional stand development along the Yukon from vegetation development following sandbar formation along the Tanana where this magnitude of disturbance is less frequent (Nossov et al. 2011). We believe these events are a significant cause of mortality of alder seedlings, which grow very slowly beneath the dense willow canopy along the Yukon River due to low rates of moose herbivory. However, sedimentation appears to stimulate vegetative propagation from basal shoots in willows. In 2011, we found that alders in plots where willows were clipped in 2009 had grown above the height to be threatened by sediments, while small alders in plots experiencing high sedimentation rates during spring 2011 were buried.

Results from our pilot study on the effects of alder on soil enzymes responsible for labile and recalcitrant organic matter turnover are preliminary but follow theoretical expectations on the effects of N on soil organic matter turnover. On a per g dry weight basis, β-glucosidase rates were more than twice as high in late succession soils than in early succession soils. When reported on a per gram C basis; however, the rates were similar, with a trend towards higher rates in early successional soils. Within early succession soils, the High Alder plots had nearly double the rates found in the Low Alder and High Willow plots, both on a per g C and per g dry weight basis. In the late successional sites there appear to be no trends associated with treatment, either on a per g dry weight basis or per g C basis for β-glucosidase. On a dry weight basis polyphenoloxidase (PPO) rates were 3 to 4 times higher in the late succession soils as compared to early; however, this result is reversed when expressed on a per g C basis. On a per g N basis, the early succession soils also had a higher enzymatic rate, but by less than twice of the late succession soils. Interestingly, the High Alder plots had the lowest PPO rates in both the early and late succession soils, by half or less. Within the early succession soils the Low Alder and High Willow were comparable, as were the Low Alder and Fertilized within the late succession soils. In general it appears that within a soil when β-glucosidase rates are high, PPO rates are low and vice versa. This result is stronger in the early succession sites than in the late succession sites.
Section III. Regional ecosystem dynamics and climate feedbacks.

Fire as simulated by ALFRESCO was enhanced through the middle of the 21st Century, after which fire activity reverted to pre-1990 levels because of a shift in forest composition to more low flammability deciduous forest (Figure 18).

Figure 18. Historical (1950 – 2006) and ALFRESCO predicted (2007 – 2099) annual burned area percentage (%) over the AKYRB region. Note that there are two ALFRESCO fire projections driven by GCM outputs of CCCMA-CGCM3.1 (CCCMA) and MPI ECHAM5 models (ECHAM5) for the A1B emissions scenario.

Simulations by the Dynamic Organic Soil version of the Terrestrial Ecosystem Model (DOS-TEM) driven by ALFRESCO fire indicate that carbon in vegetation and in soil organic horizons will decrease in response to more frequent fire in the first half of the 21st Century, but will generally accumulate after fire becomes less frequent in the middle of the 21st Century, with accumulation being slower for the warmer ECHAM5 climate (Figure 19). In contrast, carbon in the mineral horizon accumulated throughout the 21st Century. Soil temperature simulated by DOS-TEM continues to warm throughout the 21st Century for both climate projections, with the rate of warming greater for the warmer ECHAM5 climate. Similarly, DOS-TEM predicts that the area occupied by permafrost will decrease from occupying 68% of the basin in 2006 to occupying 20% and 30% of the basin by 2100 for the warmer ECHAM5 and less warm CCCMA climates, respectively (Figure 20). The DOS-TEM simulations indicate that loss of carbon in organic soil horizons and increasing air temperatures in the first half of the 21st Century
will cause the active layer to deepen across the basin from about 1 m to between 1.6 m (CCCMA climate) and 1.8 m (ECHAM5 climate) in surviving permafrost by the middle of the century and then return to current depths by the end of the century. These results suggest that there are important linkages between the fire regime, forest composition, and the structure of soil organic horizons that influence the vulnerability of permafrost degradation in interior Alaska.

Analyses of the water and energy fluxes from our different peatland sites indicate that the conversion of black spruce forest to thermokarst features in this landscape will
Figure 20: The distribution of shallow permafrost (within 5.4m of the surface) (dark blue – shallow permafrost, orange – non-permafrost or deep permafrost) in the AKYRB simulated by DOS-TEM for contemporary climate (CRU) two climate projections (CCCMA and ECHAM5) and associated predictions of fire occurrence.

decrease the water balance by 30% (Figure 21), due to an increase in ET by about 23 mm per year at the thermokarst site compared to the black spruce site. There are also large changes in daily average fluxes in the local radiative forcing across this gradient of sites (Figure 22 a, b). For example, a conversion of black spruce forest to thermokarst increases net radiation by 14% and latent heat by 12%, while a conversion of black spruce forest to fen results in a decrease in an increase in net radiation by 8% and a decrease in sensible heat by 28% (Figure 22b). Given that these ecosystems are in close proximity (< 2 km apart), an accurate assessment of the spatial heterogeneity of energy and water exchange by regional models should include ecosystems under a localized range of permafrost influence.
Figure 21. Water balance (mm), calculated as precipitation (P) minus evapotranspiration, across the spruce, thermokarst, and fen ecosystems from May – August 2011.

Figure 22. Mean daily summer energy fluxes (W m⁻²; net radiation, sensible heat, latent heat, and ground heat) at the black spruce, thermokarst, and fen sites (a), and the change in these energy fluxes (b; W m⁻²) when converting between a black spruce ecosystem to a thermokarst ecosystem, between a thermokarst ecosystem to a fen, and from a black spruce ecosystem to a fen. The numbers above the bars in (b) indicate the percent change with each conversion.
Section IV. Coupled social-ecological dynamics of interior Alaska.

Alaskan Rural Village vulnerability to changes in subsistence systems:

During 2011, we explored 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 23). 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 23. Vulnerability of a subsistence unit of analysis as determined by sensitivity and exposure to climate change](image)

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 in the Interior 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 is preliminary, as are our comparisons of Interior communities with those of the North Slope. That
comparison yielded issues related to resilience. The first we refer 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 Interior Alaska, where there are few opportunities in villages for cash resources (including jobs) and few income sources, such as dividends from oil development interests. These contrasting conditions are also related to the ability of villages to buffer in the face of economic crisis. This is illustrated in the 2007 spike in fuel process. In that case, Interior Alaska communities experienced an extreme increase in fuel costs as compared to North Slope villages that are buffered through subsidies from oil revenues (e.g., Venetie – 629% increase vs. Kaktovik – 300% increase). As a consequence 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. These social and economic conditions suggest the need for our research to think holistically about change in social-ecological systems in order to understand how various forces interact and how access to financial resources may help groups buffer against types of shock events.

Community based monitoring:

Through previous work conducted in Canada and in Arctic Village Alaska, we have found that community based 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 with accuracy human perceptions of social ecological change through time. 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 project. We plan to test this revised approach in one or two communities of interior Alaska in the coming year.
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.

Xanthe Walker, a PhD student from the Johnstone lab, collected tree-rings from pre-fire black spruce burned in the widespread fires of 2004. Tree-ring samples were obtained across a subset of 30 sites spanning landscape gradients in soil moisture that were originally established to test hypotheses concerning how fire characteristics affect successional trajectories (see task D3). Tree disks from 5-10 trees per site were collected from randomly-identified trees, sanded, and measured to obtain annual ring widths in the lab following standard dendrochronology procedures. To date, ring width series have been obtained from black spruce trees at 20 sites, and analyses are on-going.

30 extensive sites were established as part of an ongoing new site network of post-fire sites. In 2011, we concentrated on intermediate age class stands (40-60 years old) from 4 fire scars across the interior of Alaska: Big Denver (1969), Wickersham Dome (1971), Murphy Dome (1958), and Gerstle River (1947). These fires were chosen because they were road-accessible, previously sampled by LTER Senior Investigators, and predominately black spruce prior to burning. We selected stands that spanned a gradient of canopy composition ranging from deciduous to conifer that were of various site moisture status (due primarily to differences in parent material and topographic position). Rather than tying the NSN to only a few core sites, we elected to capture the landscape variability in post-fire stand structure by choosing 10 of these intermediate-age sites within each fire scar, knowing that some of these would be classified as "intensive" sites and some would become "extensive" sites. We developed a supervised vegetation classification of the entire fire scar using LANDSAT images. Using these newly-created vegetation maps as well as complementary MODIS images, we extensively explored each fire scar to develop a sense on how the factors such as site moisture, fire severity, recruitment dynamics, and herbivory were driving landscape patterns of vegetation, and then selected a minimum of 10 sites within each fire scar that ranged from dominance by black spruce to hardwoods. We also selected a limited range of mature black spruce sites that were contiguous to the fire scar, but did not burn.

Field crews visited each of these intermediate-aged sites and characterized the following: Vegetation- full releve for presence and abundance of all vascular and nonvascular species; Stand and Population Structure- Age, Size, and Species cohorts were described and given a relative % cover, PCQ along two 50 m transects
for both above and below DBH to characterize density, DBH, height, browse condition, live/dead; basal cores or disks were take for 5 individuals of each species of each cohort previously described, disks were also taken from dead standing trees that survived the previous fires (CBSNBC). Soils- organic layer depth, pH and BD of mineral layer, and probe for active layer depth that was redone late in the fall to record max active layer depth. Analyses describing the variability in post-fire community and ecosystem function are currently underway. Results from these data will determine a set of intensive long-term sites to be established as well as given a unique description of landscape variability post-fire over time.

**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 AG productivity of aspen was initiated by various senior investigators. Three aspen study sites were established in 2010 along the Tanana Valley between the Bonanza Creek LTER site and Salcha Bluff (near Harding Lake). In 2011 six new sites were established in the uplands between Murphy Dome (NW of Fairbanks) and Butte Creek (120 km NE of Fairbanks near Eagle Summit). A goal of site selection was to maximize the length of the ring width record for aspen, and these sites had the most mature aspen trees we could find. However, most trees cored had fewer than 100 rings, suggesting that the sites had initiated after fire or spruce harvest associated with mining activity in the early 20th century. The apparent vigor of aspen trees varied among sites based on the size of the June canopy, and all sites had abundant dead standing aspen stems indicating recent stand thinning. All stands were on generally south-facing slopes. White spruce and Alaskan birch were present in or near each stand, but birch was absent from the sampling area at a few of the stands. Between 11 and 14 aspen trees were cored at each of the 2011 sites in an area of approximately 2 ha. Additionally, aspen tree disks were collected, sanded and measured from 117 trees in 7 widely separated stands in central and eastern Alaska. The 2011 aspen study also collected 12 birch and 15 white spruce to provide relative growth performance of those species in the same stands.

Research was continued calibrating climate controls over radial growth of floodplain white spruce and examines whether growth in these populations responds similarly to climate as upland trees in interior Alaska. Floodplain white spruce trees hold previously unrecognized potential for long term climate reconstruction because they are the source of driftwood which becomes frozen in coastal deposits, where archeological timbers and beach logs represent well-preserved datable material. Ring width chronologies for 135 trees in six stands on the Yukon Flats and Tanana River were compared with temperature and precipitation at Fairbanks from 1912-2001.

All cores and disks were mounted and sanded, following standard dendrochronological procedures. Three of the sites (Ester Dome, UP2C, and Salcha Bluff) have been measured, cross-dated, and subjected to preliminary dendrochronological analyses. One objective under Task C2 was to explore climate sensitivity of the less well-studied species—notably aspen, birch, and balsam poplar. We have begun this work with aspen, and have preliminary data investigating climate sensitivity of aspen. We have analyzed three of the aspen sites described above,
along with two other sites from which data were collected as part of a related project (Lloyd, NSF grant ARC-0902088) and quantified climate response by using bootstrapped correlation coefficients to describe the relationship between annual ring-width in aspen and climate (using the Fairbanks climate data).

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 and Caribou-Poker Creek Research Watershed. 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 m pixel at both study areas.

**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 the 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 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.

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).

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 its effect on white spruce recruitment across 12 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 more than 13 years. In 2011 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.

During December 2010 – April 2011 we conducted four trials to measure field metabolic rates of snowshoe hares in relation to temperature. These experiments were carried out over 4 broad temperature regimes; 10°C, -20°C, -30°C, and -40°C, which reflect the typical temperature range experienced by snowshoe hares in winter in interior Alaska.

During 2011 we also conducted a study of the interaction between snowshoe hares and plant secondary metabolites (PSM) in their forage. 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 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.

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.

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.

To address how fire severity, patterns of combustion, and C and N loss from burning vary among different ecosystem types, we selected 12 burned and unburned pairs of stands from three recent wildfires. We have already collected extensive data
from black spruce stands (Boby et al. 2010); the goal of this new sampling effort was to characterize fire effects in white spruce and hardwoods (*Betula neoalaskana* and *Populus tremuloides*). In each of the stands, we assessed stand age and structure, carbon and nitrogen stocks in trees, understory shrubs, coarse and fine woody debris, and soils. In the burned stands, we also assessed combustion (% of canopy combusted) and depth of residual soil organic layer. Data from this sampling effort is currently being analyzed so there are no findings to report.

A new approach was developed to use a set of remotely sensed data products to investigate how differences in vegetation type and site drainage influence patterns of burned versus unburned vegetation within fire perimeters at a 60 m resolution. These data were used to estimate carbon consumption during 4 years (2004 and 2006-2008) (Kasischke and Hoy 2012). We recently applied this technique to added years from the 2000s, so that we now have a data set that includes 2002 through 2008. We are in the process of analyzing these data, and expect to complete this study during the upcoming year. In addition, as part of her PhD research, Liz Hoy is going to carry out a study of how patterns of burning vary as a function of fire free interval.

**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 were working towards determination of the effects of seasonal and interannual climate variation, disturbance legacies, and subsequent vegetation development on soil temperature, moisture, and the permafrost regime. To achieve this goal, we continued our efforts to record and archive the data on active layer and permafrost temperature dynamics at our sites within the Fairbanks area. This year, we visited our 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 with 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 of the existing sites (4 sites) and added new sites (2 sites) to our Permafrost Observatories Network in the Fairbanks region. In 2008, eight 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.**

See C2 for activities associated with collection of historical productivity patterns of aspen. Historical productivity patterns for aspen, can then be linked to known aspen leaf-miner outbreaks.

In the summer of 2011, an experiment was set up to test the interactive effects of willow leaf mining herbivores and mammalian browsers on succession and ecosystem function in early successional habitat on the Tanana River. We plan to complete the set up and start the experiment in the spring of 2012.

James Kruse (USDA Forest Service, State & Private Forestry, Forest Health Protection) took over the collection of forest insect population data from Richard Werner in 2011.

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.**

Johnstone, Rupp, and Verbyla worked with technician Mark Olsen to conduct simulation model experiments to examine feedbacks between changing vegetation composition and fire activity in a boreal landscape. This group tested the hypothesis that variations in surface fire severity that influence whether regenerating forests are dominated by coniferous or deciduous species may feedback to influence future fire behavior because of differences in forest flammability. They used a landscape model of fire and forest dynamics, ALFRESCO, to explore the effects of different scenarios of surface fire severity on subsequent forest succession and potential fire activity in interior Alaska. Model simulations also included scenarios of moderate and severe climate warming to assess how feedbacks between vegetation and fire behavior could affect fire responses to future climate change. The results from this modeling exercise were published in Landscape Ecology (Johnstone et al. 2011).
Kasischke has continued his analyses of factors influencing depth of burning in black spruce forests, focusing on two areas. First, his group examined the effects of trees on depth of burning. The results from this study were just published (Kasischke et al. 2012). His PhD student, Liz Hoy, collected field data to determine how fire-free interval influences depth of burning in black spruce stands. Liz completed collection of data from 39 stands that reburned during the 2000s from previous fires that burned in the 1960s. The manuscript on this research is nearing completion. Kasischke continues research on improving methods to map fire severity in black spruce forests that was first reported in Barrett et al. (2011). The techniques were refined and then applied to all large fires from the 2004 fire season.

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

In coordination with research activities described under Task D3, Taylor and undergraduate research assistant Michele Wiseman led the collection of root samples from ~1000 seedlings of black spruce (\textit{Picea mariana}), white spruce (\textit{Picea glauca}), lodgepole pine (\textit{Pinus contorta}), and trembling aspen (\textit{Populus tremuloides}) that were experimentally transplanted into 32 stands of burned black spruce forest in 2005. These root samples have been extracted and preserved for future investigations (pending additional funding) of mycorrhizal colonization that may influence the relative performance of different tree species after fire.

A variety of experimental and observational studies on tree and shrub seedlings are near completion by PhD student Rebecca Hewitt, who is under the supervision of Hollingsworth and Chapin, will shed light on the abiotic (in particular fire severity and drought stress) and biotic (in particular microbial) filters that govern seedling survival in tundra and treeline ecosystems. These studies include characterizing ecotomycorrhizal fungal communities in post-fire environments, observing mycorrhizal overlap between surviving shrubs and surrounding shrubs, and outplanting a variety of inoculated and controlled tree seedlings. Hewitt worked with collaborators from the Arctic LTER and Alaska Fire Service to obtain root tips of resprouting dwarf birch shrubs from sites of various fire severities in a large Arctic tundra fire. She then sampled pairs of spruce, birch, and aspen tree seedlings and adjacent birch or willow shrubs (roots) at the treeline sites. DNA was extracted from the root tips of the shrubs and seedlings and fungal community structure was analyzed.

Taylor and postdoctoral researcher Elizabeth Bent investigated the dynamics of joint plant-fungal re-colonization following fire using a black spruce stand within the Caribou Poker Creek Research Watershed that was burned in 2004. Seedlings of spruce, birch and aspen, along with re-sprouting alder, were collected in 2008 and 2009 in a spatially explicit, stratified sampling scheme. Shoot dry weights were determined and the fungal communities on roots were characterized using ARISA and sequencing of the nuclear ITS region. We carried out ordinations to compare fungal communities across hosts, mantel tests to examine spatial structure, and a
logistic regression to examine the potential influences of particular fungi on plant growth.

Taylor initiated a third preliminary project in 2011 to evaluate the importance of fungal dispersal and colonization to plant re-colonization after fire. He placed sterile jars to collect rainwater at three positions along a transect away from intact forest edge at the FP5C floodplain site, a black and white spruce stand that was severely burned in the summer of 2010 (Willow Creek Fire). The contents of the jars were collected after ~3 months in the field, spanning the peak of mushroom fruiting, concentrated, and preserved for later molecular analysis of the airborne spore communities.

Hollingsworth synthesized data linking plant traits to post-fire recruitment and community composition. A manuscript is near completion and should be submitted for publication within a few months (Hollingsworth et al., in prep.).

Hollingsworth, Ruess, Mack, Johnstone and others identified a series of plots that will form the New Site Network (see C1), where herbivory, key plant interactions, and community processes will be monitored. Kielland monitored the effects of herbivory on post-fire vegetation regeneration and successional processes in the exclosures within the Survey Line Fire, a 10 year old fire scar on the floodplain of the Tanana River.

Mulder and PhD student Katie Spellman’s work focuses on the invasive species (Melilotus alba), which forms dense stands along roadsides that cut through burn perimeters throughout Alaska. They have documented M. alba moving into burned areas in small numbers in previous studies. While there is little evidence that M. alba is directly altering vegetation in post-fire habitats, they hypothesized that the dense roadside M. alba could indirectly influence post-fire vegetation by altering pollination dynamics, and changing seed set in pollinator-dependent post-fire plant species. They chose to focus on pollinator interactions with Vaccinium vitis-idaea and V. uliginosum, two species that require insect pollination for sexual reproduction, and that are common in medium and low-severity burn areas. In addition, these species are a high value subsistence food resource for Alaskans. Several of the field sites for this project were located in post-fire sites within CPCRW and BNZ.

During the 2011 field season, Mulder and Spellman 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 LTER and 10 at the Caribou-Poker Flats LTER) they 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 conetainers (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 palustris 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.

Mulder and Spellman expected 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, they are using historical records to develop models linking plant phenology to climate (cumulative degree days and precipitation). They evaluated the phenological stage of specimens of these three species in the collections of the UA 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.

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

Johnstone and Mack’s primary focus for research on this task is an ongoing investigation 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. Several of the initial results from these sites have already been published that describe early environmental and successional responses to variations in fire severity (Johnstone et al. 2009, 2010, Boby et al. 2010, Bernhardt et al 2011). As part of an externally funded SERDP project (led by Schuur and Mack), Johnstone and Mack’s groups returned to these sites in 2011 to collect detailed information on tree seedling density and growth and other environmental factors detailed in D4. Demographic data will be used to calculate rates of colonization, recruitment, and survivorship for the dominant tree species and to predict future patterns of stand dominance (Johnstone et al. 2004). They also harvested half of the seedlings \( n \leq 7 \) seedlings/species/site that were experimentally outplanted at a subset of 39 intensive study sites (32 in closed forest and 9 in treeline ecotones). Seedling diameter and height were measured in the field and the aboveground biomass was harvested and returned to the lab to be sorted into stems and foliage (current-year and older), dried, and weighed. The harvest included approximately 1000 individuals of five potentially dominant tree species: black spruce (*Picea mariana*), white spruce (*Picea glauca*), lodgepole pine (*Pinus contorta*), trembling aspen (*Populus tremuloides*), and Alaska paper birch (*Betula neoalaskana*). Root samples were collected at the same time to investigate mycorrhizal colonization (see Task D2). Foliage samples are currently being processed for tissue N and C concentrations. Future analyses will focus on assessing the relative importance of
different environmental and biotic factors on species-specific patterns of tree growth and survival. By combining observations of natural tree seedling recruitment with establishment following experimental seed and transplant additions, the group hopes to be able to separate the impacts of environmental vs. demographic controls on initial successional trajectories. In addition, Hewitt will be using seedling data from a subset of sites to compare with a similar seedling transplant experiment carried out in burned tundra sites. She will be using foliar isotopes and demographic data to assess the role of drought stress or other environmental constraints on post-fire seedling recruitment in closed forest, treeline, and tundra ecosystems.

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

We have continued to collect long-term data from the network of 90 sites that were established in black spruce forests that burned in 2004 within three large fire complexes in interior Alaska (described in Task D3). In 2011, Mack and Johnstone’s groups re-measured active and organic layer depths at sites that were measured in 2005. These data will be used to link changes in active layer depth and permafrost thaw to environmental site conditions and fire severity (also recorded in 2005).

Over the last three years we have investigated consequences of fire in tundra and treeline ecosystems where historically fires have been rare. Hewitt is completing an outplanting experiment looking at survival and success rates of tree seedlings in post-fire environments at both treeline and arctic tundra. Mack, Hollingsworth and Verbyla described wildfire effects on ecosystem structure and element pools in the Anaktuvuk River Fire (2007), which burned in an area of the North Slope where there is no evidence of fire in the available 5,000 year charcoal deposition record (Mack et al. 2011). We will continue investigating the post-fire landscape, ecosystem, and community processes in the summer of 2012.

Heather Alexander, a postdoctoral researcher in Mack’s lab, has continued to explore the ecosystem consequences of alternate successional trajectories (black spruce, mixed spruce-deciduous, or deciduous) on ecosystem carbon stocks and nitrogen dynamics. Alexander et al. (in review) quantified aboveground C pools within 44 mid-successional (20-59 years since fire) forest stands across interior Alaska, where increased fire severity is predicted to shift forest composition from predominantly black spruce to greater deciduous dominance. They measured aboveground biomass and net primary productivity (ANPP) of trees and large shrubs, snags, and downed woody debris across stands of varying deciduous importance value (IV), determined by relative density, basal area, and frequency of deciduous trees and large shrubs within each stand. They assessed the influence of deciduous IV and two other explanatory variables (years after fire and stand density) on aboveground C pools by fitting a suite of uni- and multivariate regression models to the data and selecting the ‘best-fit’ model using AIC. Mack and Alexander are currently working on a second manuscript that describes nitrogen cycling across this suite of sites, and a third manuscript that describes total ecosystem carbon stocks (soil as well as vegetation) across the intermediated aged sites and 48 “mature sites.”
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 2011, 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 spatially distributed permafrost model. This model framework was applied for the Alaska portion of Yukon River Basin (AKYRB) for climate scenarios through the 21st Century. In this study ALFRESCO, DOS-TEM, and GIPL-1 models were driven by downscaled GCM outputs under the A1B emissions scenario. Output from DOS-TEM model was used to prescribe the surface vegetation and organic layer thicknesses and properties used in GIPL-1. From these simulations we analyzed changes in organic soil horizon thickness and C stocks, soil thermal dynamics, and permafrost area and active layer depth (ALD) in relation to the warming and fire regime changes from 2007 - 2099. To evaluate the impact of fire on permafrost conditions, we performed a control run of calculations with GIPL-1 model for 2000-2099 time period where 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 2011 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 with the USGS OTIS model to estimate residence time of water in stream channels, and nutrient spiraling metrics were used 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 three years of our experimental warming manipulation, and are now almost finished with the fourth winter. The third summer (2011) saw a great deal of activity measuring carbon fluxes and monitoring environmental conditions in the summer and winter warming plots. Similar to 2009 and 2010, a field crew was located at the field site initially in April when the snow from the winter warming treatment was removed. 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 installed a system for measuring winter fluxes using soda lime, which integrates fluxes from Sept until the next spring. This information is critical for extrapolating treatment differences in winter soil temperature on carbon fluxes. Another major activity during the summer of 2011 was the activation a water table manipulation 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. Lastly, Rachel Rubin, an
undergraduate at the University of Florida, finished a project to examine changes in nitrogen availability in response to warming in particular focused on plant foliar nutrients and isotopes. At the time of this report, we are planning the Year 4 field campaign to remove the accumulated snow and to install the passive greenhouses for the summer warming.

We also studied permafrost thaw in upland landscapes in 3 upland regions within the Alaska Interior using a chronosequence approach in which time-since-thaw had varied within each of the 4 upland areas. Study sites include 1) the 12 Mile Lake in the Yukon Flats, where permafrost degradation appears to have been associated with lake drainage. Successional vegetation and soils beneath this site were characterized for a chronosequence spanning about 30 years when the lake began to drain. 2) Taylor Highway north of the town of Tok, where thawing of permafrost on north-facing, bedrock slopes was triggered by historic fires: successional vegetation at this site spanned about 120 years. 3) Hess Creek north of Fairbanks, where thawing of permafrost on north-facing, loess-covered slopes was also triggered by historic fires spanning about 120 years. Soils were characterized for ice content, ice form, soil carbon and soil nitrogen.

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

We are examining how the state change associated with permafrost thaw and thermokarst in forested peatlands regulates ecosystem carbon balance and nitrogen availability. As part of a recent NSF DEB-funded project, chamber-based CO₂ and CH₄ fluxes and vegetation productivity were quantified from 2008-2011 in a forested permafrost peat plateau and two adjacent thermokarst bogs located near the Bonanza Creek Experimental Forest (BCEF). Air photograph interpretation suggests that one thermokarst bog thawed between 1972 and 1983 (older collapse), while the second thermokarst bog thawed between 1983 and 1994 (more recent collapse). With USGS funding, we recently installed two year-round eddy covariance towers, one in the permafrost plateau and another in the young thermokarst bog. Each is instrumented with CO₂ and H₂O fast response gas analyzers and a number of meteorological sensors (air temperature, soil moisture and temperature at various depths, relative humidity, precipitation, albedo, photosynthetically active radiation, etc.). There are also 8 autochambers within the footprint of each tower.

Three chronosequences of permafrost thaw are being investigated in Interior Alaska: Koyukuk Flats National Wildlife Refuge (O'Donnell et al. 2011); Innoko Flats NWR; Bonanza Creek LTER (abstracts by Klapstein; Waldrop from AGU 2011). At Innoko and Koyukuk, there is a clear response of methane release to thermokarst in the lowland peats, with the methane emissions gradually increasing until the thermokarst landforms are several decades old. Thereafter, by the time the landforms have established thick, acidic bogs, the methane emissions decline to pre-thaw levels. This time-lag in methane release coincides with a plant community shift and exposure of open water as the ice-rich permafrost thaws and ponds at the surface. At
the Bonanza Creek LTER, there is also a buildup of methane release but the time-lag may be only 1 or 2 decades to reach the maximum methane emissions.

**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 integrate 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 2011, 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 will be complete this summer, and we hope to formalize a coordinated sampling design with the aerial survey program by the time the lines are flown this 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. Results from our 2010 repeat canker survey are reported below in Findings.

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 July 2011. All willow and poplar shoots were clipped to 50 cm above the soil surface, and alders were counted and measured for DBH and height.
In the summer of 2011, we studied soil enzyme kinetics in soils from six sites within the Bonanza Creek LTER. Specifically we were interested in the turnover rates of labile and recalcitrant carbon pools in early and late succession soils with different nitrogen levels, and how N-fixation inputs by alder affects activities of soil enzymes to influence decay and storage of soil organic matter. The early succession sites were: 1C-A, 1C-B, and Deb's Island. The late succession white spruce sites were: 4A, 4B, and 4C. From within the early succession sites, sub-plots were selected according to the presence or absence of willow and alder. These we referred to as “High Willow,” “High Alder,” and “Low Alder.” Within the white spruce sites, sub-plots were determined as “High Alder,” “Low Alder,” or “Fertilized.” From each of these sub-plots, six soil cores were collected and taken back to the lab on ice, where the top 5 cm was removed and pooled for enzymatic analysis. We measured the turnover of labile carbon with activity of the cellulose degrading enzyme β-glucosidase by fluorescent detection with the plate reader. We also determined rates of polyphenoloxidase (PPO) activity as a measure of recalcitrant lignin degradation with the colorimetric conversion of the substrate L-DOPA, again using the plate reader. Assays were conducted on an unfiltered slurry of field moist soil in sodium acetate buffer at pH 5.5. We also determined percent moisture, total C, and total N for all pooled soils. This allowed us to report results on a per g dry weight, per g C, per g N basis.

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 15\textsuperscript{th} continuous year (US Forest Service 2011, Werner & Kruse 2011). Feeding damage by \textit{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 interior Alaska as well over the past 20 years; the most outbreak flared in 2009 and was still ongoing in 2011. Ambient levels of attack by \textit{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.

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. In spring and summer 2011, we chose 6 study sites distributed along the Tanana River, in early successional habitat dominated by \textit{Salix interior}, \textit{S. niphoclada} and \textit{S. pseudomyrsinities}. All three species of these willow species are susceptible to attack by the willow leaf blotch miner, \textit{M. salicifoliella}. The experiment is designed as a 2-way, split-plot design, with vertebrate exclusion as the whole plot factor and invertebrate exclusion as the sub-plot factor. Fencing to exclude vertebrates was procured and transported to study
sites. The experiment will begin in spring 2012, when half of the study plots will be fully enclosed in fencing to exclude vertebrates and half of each plot will be sprayed with insecticide to reduce damage by *M. salicifoliella* and other insect herbivores. Data collection will commence in summer of 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.

Changes in vegetation and soil properties following permafrost degradation and thermokarst development may cause changes in carbon, water, and energy cycling. In order to better understand these dynamics, we established three sites in interior Alaska across a gradient of permafrost in which permafrost varies in presence and stability. These sites include a black spruce ecosystem with cold soils and stable permafrost, a permafrost collapse scar with thermokarst formation, and a moderately rich fen lacking near surface permafrost. Measurements at the sites include year-round eddy covariance estimates of CO₂, water, and energy fluxes as well as the associated micrometeorological variables.
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 methanogensis, 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.

Activity Statement for CF1, CF2, and CF4: We coupled the outputs of the Alaska Frame-Based Ecosystem Code (ALFRESCO) to the Dynamic Organic Soil version of the Terrestrial Ecosystem Model (DOS-TEM) to evaluate the degree to which feedbacks between forest composition and fire regime influence soil organic horizons and permafrost integrity in a warming climate in interior Alaska. The coupled model framework was driven by retrospective climate (1901 – 2006) and downscaled global climate model (GCM) output at 1 km x 1 km for the AKYRB from 2007 – 2009. ALFRESCO is a landscape simulation model that simulates interactions and feedbacks among fire, climate and vegetation in interior Alaska. DOS-TEM has been designed to explicitly represent the effects of fire on interactions among soil thermal and hydrologic dynamics, the structure of organic soil horizons, and ecosystem biogeochemistry. DOS-TEM, which represents multiple soil C pools of different quality within different layers of the organic and mineral soil horizons, was parameterized, calibrated and validated for black spruce forest, white spruce forest, deciduous forest, and tundra in interior Alaska. In this study ALFRESCO and DOS-TEM were driven by downscaled outputs of two global climate models (CCCMA and ECHAM5) under the A1B emissions scenario. The outputs of fire occurrence and severity simulated by ALFRESCO were used to drive DOS-TEM. From these simulations we analyzed changes in organic soil horizon thickness and C stocks, soil thermal dynamics, and permafrost area and active layer depth (ALD) in relation to the warming and fire regime changes for a retrospective climate period (1950 – 2006) and for a projected climate period (2007 – 2099). We are currently conducting a factorial modeling experiment to quantify the relative effects of climate and disturbance on simulated carbon dynamics. Although the modeling framework does not yet have the capability to evaluate methane dynamics, we have been developing and testing a methane module that is integrated with DOS-TEM.

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. This effort included collaborations with ADFG / Div of Subsistence staff who are familiar with their "Community Profiles DB." We also met with staff at the Council of Athabascan Tribal Governments to request access to harvest data for seven villages of eastern interior Alaska. The conversation with CATG is on-going. CATG is interested in collaborating with this project but has requested that we talk more to understand villages' political vulnerabilities if releasing harvest and traditional use data. Based on the ADFG reports and data, we compiled a DB to identify all species referenced in the DB and report and evaluated those species with respect to their contributions to total pounds harvested.

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

This area of work builds on the NSF project “IPY: Impact of High-Latitude Climate Change on Ecosystem Services and Society” (0732758). That project included interviews with local subsistence harvesters to document knowledge of how environmental conditions affect availability of resources. Part of the work documented local observations 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 SNAP office (Scenarios Network for Alaska Planning) to identify best available science and spatially explicit downscaled climate models to assess the implications of climate change on villages ecosystem services.

In the summer of 2011 we convened a meeting of Maps and Locals (MALS) researchers from across the LTER Network to discuss methods for integrating local knowledge with GIScience. As a part of that effort, a synthesis paper was written about the utility of integrating these knowledge systems and a proposal involving 6 LTER sites was developed and submitted to the NSF CHNS Program for future work. As well, we worked with USFWS / Arctic Refuge staff to initiate a community-based monitoring program in one or more interior Alaska villages. We are exploring the plan to include Venetie and Nanana in this monitoring program and other social-ecological systems research of our LTER program.

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.

Household economic and subsistence data collected from the BOEM (formerly MMS) funded project, “The Study of Sharing Networks to Assess the Vulnerabilities of Local Communities to Oil and Gas Development Impacts in Arctic Alaska” have been collected for the village of Venetie, Alaska. We are now analyzing those data to identify patterns in household involvement in the cash-subsistence economy and to construct social network graphs of inter-household and inter-community cash and
subsistence resource sharing. These data and analyses will serve as the basis of assumptions in our future modeling. We also conducted a preliminary analysis comparing the vulnerability of a North Slope and Interior Alaska village.

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

The work of this is just getting initiated. The first effort is focused on policies related to predator management, which is focused on analyzing transactions of the Alaska Board of Game, the body that makes regulatory decisions on predator management.

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

A group of communities were engaged in a conversation about completing task SE5. That group of residents stated a strong preference to not focus on community adaptation or resilience, but instead to focus on community self-reliance. Those discussions are on-going with plans to engage specific communities on that topic in further discussions.