CLIMATE-DISTURBANCE INTERACTIONS IN THE
ALASKAN BOREAL FOREST

Background

The Bonanza Creek (BNZ) LTER program was initiated in 1987 to study succession in the Alaskan boreal forest. The successional paradigm that emerged from this research is based on Jenny's (1941) state factor approach. The Central Hypothesis of the initial research program was that “the pattern of succession is determined primarily by the initial soil physical and chemical environment of the site and by the life history traits of component species. The rate of successional change is determined by vegetation-caused changes in environment and ecosystem function.” Our research has largely supported this hypothesis (Yarie et al. 1998) but showed that successional pattern in the boreal forest is regionally variable (Mann and Plug 1999), reflecting stochastic variation in disturbance and recruitment.

The boreal forest is the second most extensive terrestrial biome on earth (Whittaker 1975) and has many characteristics that set it apart from other ecosystems. It has a cold dry climate, making it potentially sensitive to climatic change. It has few dominant tree species, so changes in these tree species have large ecosystem impacts. It is relatively undisturbed by current human activities. Productivity is low relative to other forests, but boreal forests provide habitat for fish, grazers, and birds, and are used by people for recreation, hunting, fishing, and timber. During the relatively brief (10,000 yr) history of the boreal forest in its current location, it has experienced radical changes in climate, vegetation, and fauna (Muhs et al. In press). Warming during the last 25 years (Serreze et al. 2000) has been associated with warming and melting of permafrost (Osterkamp and Romanovsky 1999), changes in growth rates of dominant trees (Judy et al. 2000), increased area burned (Kasischke et al. 1999), insect outbreaks (Malmström and Raffa 2000), and changes in vertebrate populations (Stephenson et al. In press). We do not yet know all the causal links among these changes, nor their implications for the functioning of the boreal forest and the people who inhabit this region. Research in the Bonanza Creek LTER focuses on documenting these changes, their causes and interactions, and their implications for regional sustainability (Chapin and Whiteman 1998).

The structure and functioning of the boreal forest determines and is influenced by its disturbance regime (Mann and Plug 1999). Millions of hectares of the Alaskan Interior burn each decade. The extent and distribution of these disturbances are changing rapidly as climate warms, as fire control is intensified near population centers (Kasischke et al. 1999), as timber harvest expands to meet the fiber needs of a growing human population (Melillo et al. 1996), and as insect outbreaks increase with climatic warming (Malmström and Raffa 2000). In order to understand the current and future structure, diversity, and functioning of the boreal forest, we must understand the interactions between changes in climate and disturbance regime.
Our research has important implications for the global system. The boreal forest contains 40% of the world’s reactive soil carbon (McGuire et al. 1995). Boreal forests could be part of the "missing sink" of CO₂, if they are accumulating carbon (Randerson et al. 1999) or a carbon source if recent warming trends enhance fire frequency or decomposition more than they enhance plant production (Zimov et al. 1999). The boreal forest also influences climate through regional energy exchange and the hydrologic cycle. The northward movement of the arctic treeline could amplify the expected rapid climatic warming at high latitudes (Bonan et al. 1995). Alternatively, increased deforestation or a shift from predominance of conifer to deciduous forest resulting from logging or fire could cause regional cooling (Chapin et al. 2000). The boreal forest accounts for 80% of the watershed area that drains into the Arctic Ocean. The quantity and salinity of water that moves from the Arctic Ocean to the North Atlantic influence deepwater formation and the strength of the thermohaline circulation that drives latitudinal heat transport by the earth’s oceans. Changes in this circulation are implicated in past switches between glacial and interglacial periods. Thus, the boreal forest plays a critical but uncertain role in the future climate of the Earth.

There is evidence for both stability and rapid change in boreal ecosystems at all time scales. At large temporal and spatial scales, the boreal forest has responded sensitively to climate, with changes from birch-shrub tundra to poplar woodland (9,000 to 12,000 yr BP) to white spruce forest (5,000-9,000 yr BP) to a landscape mosaic with abundant black spruce forests (4,000-6,000 yr BP) (Edwards and Barker 1994). Fire frequency increased dramatically with the arrival of black spruce, despite the trend toward a cooler wetter climate at that time, indicating strong vegetation effects on fire regime. During the last 1,000 years, the vegetation has remained remarkably stable, despite large changes in climate, including the medieval warm period, the Little Ice Age, and recent warming to temperatures that are the warmest in 400 years (Overpeck et al. 1997). The apparent stability during the last millennium suggests that no new thresholds existed for new migrations. However, potential migrants, such as lodgepole pine, have already migrated the Alaskan border from the east and been planted in interior Alaska, so imminent future changes in forest dominants are plausible.

Abrupt changes in ecosystem functioning occur in Alaskan forest succession because there are only 1 or 2 dominant tree species in any one stand, and each of these species exerts strikingly different effects on ecosystem processes. Consequently, successional changes in forest dominants translate into strong autogenic control over biogeochemical and population processes. However, many of the processes that generate these repeatable patterns are stochastic and regionally variable. The boreal forest is constantly rebounding from a series of past “extreme” events. Stand-replacing fires occur every 40-200 yr (Mann and Plug 1999). White spruce recruitment following fire requires seed dispersal onto a mineral seedbed within 5-10 yr after fire. Good cone crops occur only every 3-10 yr, however and seeds disperse only modest distances. Plant mortality from herbivory (snowshoe hare, spruce budworm, larch sawfly, aspen tortix, birch spear-marked black moth) and snow-breakage events occur in pulses separated by years or decades. Together, these events introduce a stochastic element to vegetation dynamics that contributes to substantial variation in species composition and successional trajectory across the landscape.
Conceptual Framework

The central question in the BNZ LTER research is: How do changes in climate and disturbance regime alter the functioning of the Alaskan boreal forest? Our overall objective is to document the major controls over community dynamics, biogeochemistry, and disturbance and their interactions in the face of a changing climate. The research is organized around three interactive themes: (1) Forest dynamics; (2) The changing boreal carbon cycle; and (3) Regional and landscape controls over disturbance regime.

The forest dynamics theme addresses successional changes in population and community processes following disturbance. We examine the relative importance of historical legacies, stochastic processes, and species effects (autogenic processes) in determining successional trajectories and the sensitivity of these trajectories to climate. An improved understanding of forest dynamics and their mechanistic controls is essential to management for forest products, wildlife, and forest health. Changes in the carbon cycle during succession hinge on changes in forest dynamics and other element cycles, but also influence nutrient availability and microenvironment and therefore successional changes in forest dynamics. Climate affects the carbon cycle directly through changes in net primary production and heterotrophic respiration and indirectly through changes in species composition and their effects on biogeochemistry. An improved understanding of the boreal carbon cycle is critical to projections of future changes in global carbon and climate dynamics. Regional and landscape controls over disturbance regime focuses on regional and landscape processes that are responsible for the timing, extent, and severity of disturbance. Disturbance regime is affected by and influences successional trajectories of forest dynamics and biogeochemistry. Understanding controls over disturbance regime is critical to long-term regional planning for sustainable use of natural resources.

Research Design

Intensive sites. Our intensive research sites are at the Bonanza Creek Experimental Forest (BCEF), which is dissected by the glacially fed Tanana River, and the Caribou-Poker Creek Research Watershed (CPCRW), which has several well-defined upland watersheds. Our intensive studies focus on three chronosequences: succession following flooding in the Tanana River floodplain at BCEF, post-fire succession on south-facing uplands at BCEF, and post-fire succession on north-facing uplands at CPCRW. These sites enable us to compare primary and secondary succession and to compare post-fire succession in two dramatically different thermal and disturbance regimes. The floodplain-upland contrast allows us to compare a moisture-rich system (floodplains) with a moisture-limited upland system. The post-fire successional sequences allow us to compare warm, dry, south-facing slopes without permafrost to north-facing, permafrost-dominated slopes. For each of these sequences we study early, mid, and late successional sites, except in the floodplain, where the more complex successional dynamics require six successional stages. Each of these stages is replicated three times. In many of these intensive sites we have experiments to test the importance of particular processes. In each successional stage we measure microenvironment continuously, those population and ecosystem variables that respond sensitively to climate annually (e.g., litterfall and tree diameter increment), and slow variables (e.g., species composition and biomass) at 1-6 yr intervals depending on rate...
of successional change. For those processes that occur most actively or have greatest impact in particular stages (e.g., establishment of tree seedlings and mammalian herbivory in early succession), we focus intensive effort on these stages and use less intensive observations at other stages.

**Modeling.** We use four types of models that operate across a range of spatial and temporal scales to integrate our results in time and space and as a mechanism for testing proposed linkages between pattern and process. (1) Stand-level population models include models of small mammal population dynamics and herbivory (Rexstad 1994) and an individual-based model of tree population dynamics [SKOG]. (2) Soil thermal and hydrologic models simulate permafrost temperatures and the probability of thermokarst within stands. (3) The Alaska Frame Based Ecosystem Code (ALFRESCO) is a landscape model based on the turning point theory of our previous LTER research. It simulates the interactions of climate, fire, and landscape structure in causing shifts in landscape structure and disturbance spread. (4) The high-latitude version of the Terrestrial Ecosystem Model (TEM), which simulates the major C and N fluxes and pools sizes of ecosystems, incorporates understanding gained from soil thermal and hydrology models. TEM has been applied at a variety of spatial scales (stand-level to regional) and temporal scales (seasonal to century) to evaluate the carbon dynamics of high latitude ecosystems.

**Temporal scaling.** To assess past interactions between climate, disturbance, and ecosystem properties, we focus on three time scales: (1) the last 300 years, during which climate has warmed (tree rings), (2) the last 1,000 years, which includes relatively rapid, low-magnitude climate changes of the LIA as recorded in lake cores, and (3) lower-resolution records from lake cores for the past 12,000 years, which includes the entire history of the boreal forest, including the period ca. 10,000-6000 yr B.P. when conditions were probably warmer and drier than present.

**Major recent results**

**Environment**

Upland and floodplain forests that we study in the BNZ LTER develop in fundamentally different geochemical environments and differ in the causes of nutrient limitation. 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 (Yarie et al. 1998). 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. 1999) 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. 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. 1991). 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), 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. (Serreze et al. 2000). Tree-ring analysis shows that this warming is unprecedented in the past 200 years (Barber et al. 2000). 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. 2000a).

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.

Forest Dynamics

The differences in environment and disturbance regime between upland and floodplain and between north-and south-facing slopes promote colonization by different plant species, leading to different successional trajectories (Yarie et al. 1998). [See detailed vegetation descriptions on the BNZ website.] Following plant colonization in this low-diversity biome, the successional change in dominant forest species results in dramatic threshold changes in the physical and chemical environment. For example, alder invasion in early succession increases nitrogen availability and productivity (Uliassi et al. In press, Uliassi and Rue ss Submitted). The late-successional change from deciduous trees to spruce alters the physical structure of litter, allowing the establishment of mosses. These mosses insulate the soil and greatly reduce soil temperature, decomposition rate, and nitrogen supply (Van Cleve et al. 1996). The switch to the moss-conifer-dominated ecosystem, dramatically increases flammability and probability of fire (Rupp et al. submitted). These turning points associated with changes in the dominant tree species are some of the most dramatic examples of species effects on ecosystem processes that have been reported and are likely to occur in many low-diversity ecosystems (Chapin et al. 2000b).

Succession produces repeatable patterns in species diversity (Rees 1997, Waide et al. 1999), with hot spots of insect and bird diversity in early successional floodplain stands (Johnson unpubl.) and nonvascular diversity increasing in late successional spruce forests (Willsrud 1997). Early successional plants exhibit a broad spectrum of tannins that have species-specific effects on insect herbivores (Ayres et al. 1997). The resulting host specificity contributes to the high insect diversity in early succession. Climate and land use are the global-change drivers that will probably have the greatest
impact on boreal diversity over the next century (Rees 1997, Chapin and Danell In press, Sala et al. 2000).

Mammalian herbivores strongly influence the rate of successional change. Selective browsing by moose and hares on pioneer willows leads to the competitive release of mid-successional species such as alder and poplar (Kielland and Osborne 1998) and accelerates successional change (Kielland and Bryant 1998). The browsing-induced reduction in canopy density has cascading effects on nutrient cycling through changes in physical environment, litter chemistry, and the proportion of nutrients returned as feces (Kielland et al. 1998, Kielland and Bryant 1998). Moose account for a third of the aboveground nitrogen input to soils in the willow stage (Kielland and Bryant 1998), indicating a key role of herbivory in the biogeochemistry of early succession. Herbivory also connects riparian and stream ecosystems. Winter browsing of birch by moose changes the chemistry of leaves in the following growing season, increasing the quality of dissolved organic carbon (DOC) leachates derived from the leaf litter, in turn, increasing use of DOC by stream microorganisms (Estensen et al. in review).

Coarse-resolution analysis of Holocene pollen cores indicates that regional expansion of white spruce ca 8500 yr BP and of black spruce 4500 yr BP coincided with increased effective moisture. This is consistent with LTER dendroecological data indicating strong moisture limitation to white spruce growth (Barber et al. 2000). The black spruce expansion was accompanied by increased charcoal, suggesting a vegetation-induced increase in fire frequency, despite the wetter climate (J. Clark, unpubl.). This surprising result indicates a pronounced effect of vegetation on fire regime.

In summary, topographic differences in physical environment and disturbance regime give rise to strikingly different suites of initial colonizers and successional trajectories between floodplains and north- and south-aspect uplands. The pattern of species change after colonization is controlled by herbivory and by strong plant species effects on the soil physical environment, biogeochemistry (see below), and disturbance regime. These strong species effects reflect the low functional diversity of trees in boreal forest and their interaction with understory mosses.

Production and Biogeochemistry

Tree ring-climate correlations, carbon isotope analyses, and experimental manipulation of water and nitrogen suggest that, despite the cold climate, water and nitrogen primarily limit the productivity of upland white spruce stands (Barber et al. 2000, Billings 1998). Allocation, however, is responsive to temperature. Alaskan interior forests have the highest allocation to root production of any forest yet reported. This high proportion of total ecosystem C allocated below ground contributes to large soil C stocks. Most soil respiration is derived from root rather than heterotrophic respiration (Ruess et al. 1998). Approximately three times more N is cycled through fine roots than through aboveground litterfall. These studies indicate the critical role of the belowground environment in explaining patterns of production.

Successional changes in vegetation dramatically alter carbon and nutrient turnover. In the floodplain, for example, nitrogen fixers add nitrogen and organic matter (Uliassi et al. In press, Uliassi and Ruess Submitted), which acidifies the soil and increases the availability of both N and P. When poplars dominate, their tannins cause a
decline in N₂-fixation, but provide sufficient labile C to enhance N mineralization (Schimel et al. 1998) and N supply to vegetation. As spruce replaces poplar, the increase in lignin content, C:N ratio, and lignin:N ratio and the moss-induced decline in soil temperature together reduce decomposition and N mineralization (Yarie et al. 1998). These are among the best-documented examples of vegetation-driven changes in biogeochemistry.

Vertebrate herbivory also affects soil processes. The warm dry soils of heavily browsed early successional sites have higher rates of soil respiration and higher decomposition potentials than do browser-free exclosures (Kielland et al. 1997). The high decomposition rates in browsed areas reflects increased labile C and N concentrations in litter (Kielland et al. 1997) and increased root turnover (Kielland et al. 1997, Ruess et al. 1998). The combination of reduced fine root biomass (Rosswow et al. 1997) and increased root turnover in browsed areas leads to a reduction in soil C content outside the exclosures.

The biogeochemistry of Alaskan boreal forests has important implications for trace-gas feedbacks to the atmosphere. Upland Alaskan forests are a sink for atmospheric methane. N addition inhibits CH₄ consumption at some sites but not others, due to site differences in CH₄ oxidizer populations rather than to differences in N cycling (Gulledge and Schimel 1998b, Gulledge and Schimel 1998a, Gulledge et al. 1998). This work is one of the strongest examples of ecosystem processes being controlled by the structure of the microbial community. Models based on LTER research suggest that interior Alaska is currently a net sink of CO₂ (McGuire and CCMLP Submitted, Yarie and Billings Submitted) but that interannual variation in climate and disturbance strongly affect the direction and magnitude of carbon exchange (McGuire and CCMLP In press).

In summary, the major state factors (climate, topography, parent material, biota, and time) each exert strong effects on ecosystem processes in the boreal forest, leading to important interactions among microclimate, soil resources, functional types of organisms, and disturbance regime. The vegetation-driven changes in biogeochemistry are critically important in explaining patterns of successional change.

Hydrology and Aquatic Processes

Permafrost is a major "ecological adjective" modifying hydrology, thermal regimes, chemical fluxes from uplands to streams, and biotic processes in streams (Oswood 1997). Stream flow from permafrost-dominated watersheds has more dissolved organic C but less dissolved minerals than in permafrost-free watersheds (MacLean et al. 1999). Permafrost apparently acts as a partial barrier to percolation of water from organic soil horizons to underlying mineral soils and so generates rapid storm-flows rich in dissolved organic C but relatively impoverished in dissolved minerals (MacLean et al. 1999). The recent warming and melting of permafrost has important implications for the coupling of land-water systems at high latitudes.

1.1 Regionalization

We have developed regional data sets of input parameters required for regional modeling. Maps of climate (Mock et al. 1998, Fleming et al. 2000) document the
geographic pattern of warming from the 1960s to the 1980s. Decadal maps of fires since 1950 (Kasischke In press) and of lightning strikes (Dissing and Verbyla submitted) suggest an increase annual area burned in western Canada (but not in Alaska) in the last decade (Kasischke et al. 1999), presumably due to warmer temperatures and lower fuel moisture. Bark beetles have eliminated spruce forests over broad areas of southern Alaska in association with recent warming but have not yet reached outbreak proportions in interior Alaskan forests (McCullough et al. 1998, Malmström and Raffa 2000). Our 20-year population record of major insect defoliators indicates high populations of several insect defoliators in BCEF within the past decade. An examination of the spatial distributions of Alaskan freshwater fishes using 2 frameworks, ecoregions and hydroregions (drainage basins), showed that the distribution of Alaskan freshwater fishes is complexly determined by ecophysiological requirements of fishes along the latitudinal gradient from northern rain forest to arctic tundra, by current and past barriers to dispersal, and by the legacy of Pleistocene glaciation (Oswood et al. 2000).

A 200-yr chronology of river height developed from correlations of river height at LTER sites (1989 – present) and USGS gauging stations (1962 – present) and a 200-yr ring-width chronology for the floodplain (Yarie et al. 1998, Adams 1999) indicate large variation in flood frequency but no directional trend.

**Synthesis and Modeling**

Our modeling has used LTER data on ecosystem processes to develop and parameterize models as a basis for extrapolating results to the regional scale. For example, a carbon balance model parameterized from black spruce data in Alaska reproduces the seasonal and interannual variation in net ecosystem carbon exchange in the BOREAS old black spruce sites in Canada (Amthor et al. In press, Clein et al. In press, Potter et al. Submitted). We then apply these models at larger scales to estimate the current carbon budget of Alaska (McGuire and CCMLP In press, Yarie and Billings Submitted) and future scenarios of carbon storage at the circumpolar scale (McGuire et al. In press-b, Clein et al. In press). We have also used these models to explore the role of winter ecosystem processes of high-latitude ecosystems in seasonal aspects of the global carbon cycle (McGuire et al. In press-b). Sensitivity analyses with these models highlight the importance of: (1) root dynamics and labile soil carbon in C-budget models; (2) vegetation structure (specifically trees and moss) in soil thermal models; and (3) C-N interactions in predicting future forest productivity. Changes in vegetation caused by climatic warming could have profound regional effects on landscape processes, including fire spread, seed dispersal and feedbacks to climate. We document these changes through remote sensing and explore their consequences through landscape-scale modeling of fire-climate-vegetation interactions (Rupp et al. 2000, Rupp et al. In press a, Inpress b).

We have integrated our research into a larger context through participation in many LTER cross-site comparisons and through a synthesis of high-latitude ecosystem feedbacks to climate involving comparisons of ARC and BNZ LTER sites and the BOREAS sites in Canada (Chapin et al. 2000). Together with HJA, we have contributed to an effort by the US Vice President and Russian Prime Minister to develop ILTER sites in Russia.
Summary
Research at the BNZ LTER site has contributed substantively to understanding the relationship between “independent” state factors and internal ecosystem dynamics in causing successional change. We have shown that:
1. Species effects are strong in the boreal forest.
2. Successional changes in species composition are not a simple consequence of changes in competitive balance but involve species-driven changes in biogeochemistry and the physical environment.
3. Vertebrate herbivores are a powerful force driving successional change through their effects on plant competitive interactions and biogeochemistry.
4. Succession influences exchanges of CH₄, CO₂, water, and energy in ways that could feed back to climate.
Outreach efforts

The BNZ LTER has substantially expanded its efforts at outreach in the areas of K-12 education, development of formal ties with other research programs, museums and agencies, and organization of science symposia. We have hired a site manager (a new position), one of whose responsibility will be to augment our outreach to the general public.

Education

As part of the LTER schoolyard program, we have teamed up with two ongoing science education programs, GLOBE (NASA) and Partners in Science to train science teachers in 15 Alaskan towns and villages. LTER funding enabled six Fairbanks elementary and high school teachers to be added to the program. We have initially focused attention on teachers in close proximity to our LTER site to explore how best to integrate education with our research program.

In addition to the formal LTER schoolyard program, individual LTER PIs have taught short courses for secondary school science teachers from rural Alaska (Oswood and Bryant), developed web-based curricula in long-term ecological monitoring (Verbyla, Sparrow, and Juday), worked in rural schools to describe the LTER science program (Lloyd), taught about LTER science in local environmental summer camps for grade school students (Rexstad), involved high school students in LTER research projects (Ruess and Chapin), taught lessons in climatology and helped establish climate and soil monitoring stations in local schools (Hinzman), and acted as judges for the local elementary and secondary school science fairs (many PIs).

Ties with other LTER sites

The BNZ provides a logical comparison with many other LTER sites, particularly the vegetation types that are immediately north (Arctic [ARC] LTER site) and south (HJ Andrews [HJA] LTER site). We have worked closely with these two sites to develop programs that will maximize the opportunities for comparative studies. Our collaborations with the Arctic LTER site are directed towards understanding Alaska as a regional system in which the boreal forest and tundra are linked by many common biotic components and by the atmosphere. We are developing museum collections and a sample archive that will serve both the ARC and BNZ sites. With HJA we are developing common protocols in studies of hydrology and vegetation feedbacks to climate.

Ties with Alaskan long-term ecological research programs

Our LTER science symposia and active solicitation of collaborations with agencies have created closer links with several long-term ecological research programs in Alaska. We are collaborating with the Long-Term Ecological Monitoring (LTEM) program of the National Park Service to use the same regional sampling protocols, hierarchical vegetation classifications, and climate monitoring programs. Two LTER investigators (Rexstad and Juday) also work in the LTEM, providing direct communication between the two programs.
Collaborative arrangements provide the LTER access to population and habitat data from the Alaska Department of Fish and Game (ADF&G). We are developing a GIS database of previous forest harvests with the Alaska Division of Forestry (DOF). We worked with the EROS data center of USGS to develop statewide maps of climate, vegetation, and other variables at the 1-km scale. The BNZ LTER collaborated with the Alaska Fire Service (AFS), a section of BLM, to burn a 740 ha watershed in CPRCW in July 1999 (FROSTFIRE). As follow-up, the LTER initiated regular seminars allowing interchange between scientists from LTER and agencies (AFS, ADF&G, DOF, etc.). An explicit objective of these seminars is the development of models that link climate, fire, post-fire succession, and wildlife habitat. AFS has offered to do additional prescribed burns to meet LTER science needs. Our long-term goal is to identify and make accessible all the long-term data bases in Alaska that are useful for ecological modeling. We provide links to agency web sites where data are available, provide on our web site a list of data sets and contact information, or will post these data on our web site, as a last resort.

Ties with museum collections

Using LTER supplement funding, we have worked with the University of Alaska Museum to develop collections of plants (herbarium specimens and tissue collections), insects, and vertebrates that provide both a long-term record and a broad spatial record of genetic and species diversity of Alaska. We have also initiated discussions with them about how to proactively design the optimal long-term collections program, rather than to be passive recipients of specimens that are brought to the museum. We anticipate a strengthening of this tie with the Museum, as we strengthen the biodiversity component in our regionalization studies.

Involvement in forest management issues

In 1997, we held a workshop on the ecological role of forest harvest in interior Alaskan forests. This workshop presented perspectives from state and federal land managers, native groups, commercial interests, and ecologists. We developed a conceptual model of the role of human activities as an integral component of the boreal forest and determined that, in the next two decades, human decisions about fire control would have much greater impact on the boreal forest than would forest harvest. We seek external funding to explore the role of humans as components of the Alaskan regional system. We plan a second symposium on forest harvest.

Wurtz occupies the Forest Science seat on the Citizens' Advisory Committee for the 1.7 million-acre Tanana Valley State Forest. Juday has participated in training sessions for the Alaska Division of Forestry, the Bureau of Land Management, and the National Park Service. Several LTER scientists have contributed to articles sponsored by the Society of American Foresters in the local newspaper and to the occasional newsletter "Forest Science Notes" published by the UAF Dept. of Forest Science.

Outreach to the general public

LTER scientists (Juday, Romanovsky, Chapin, Finney, and others) have been interviewed by numerous radio and television stations (NBC, CBS, ABC, public television and radio, Danish Broadcasting System) and newspapers (New York Times,
local Alaskan newspapers) about the impact of global warming on boreal forests. Juday was an invited speaker in the Congressional Seminar series, sponsored by U.S. Global Change Research Program, Washington. The audience included members of Congress and staff, constituencies involved in U.S. global change policy, and agencies involved in global change research. NOVA film crews interviewed LTER scientists and filmed the FROSTFIRE experimental burn as part of a major television series on the ecological role of fire. Hinzman led four public meetings to explain the science of the Frostfire project.

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Books


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