GLOBAL CHANGE IMPACTS IN THE COLORADO ROCKIES BIOGEOGRAPHICAL AREA FINAL REPORT, 1999-2003

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INTRODUCTION

Phase I of our global change research program (1992 to 1998) consisted of three integrated studies designed to: (1) develop an understanding of the abiotic and biotic controls on forest distribution and productivity as a basis for assessing potential vegetation change for a range of projected climate scenarios; (2) project a range of possible scenarios of future climate change for the Colorado Rockies; and (3) evaluate potential responses of hydrologic and aquatic ecosystem processes to climate change at watershed, drainage basin, and regional scales. Phase II of our research program (1999 to 2003) focused directly on how rapid environmental change affects key natural resources and processes in Rocky Mountain National Park and the surrounding region. We used our interdisciplinary, ecosystem science approach to identify high priority issues as identified by Park resource managers, including: (1) providing better climate change scenarios to land managers to assess the vulnerabilities of ecosystems to rapid environmental change; (2) assessing how climate change influences natural watersheds (e.g., Loch Vale, Rocky Mountain National Park); (3) developing GIS-based disturbance history maps (fire and insect outbreaks) to aid the Park's Fire Management Program; and (4) determining how climate change, vegetation management practices, and disturbance affect the spread of non-native plants and aspen regeneration.

OVERVIEW OF PROGRESS AND RESULTS

We have made substantial findings in our integrated study of Global Change in the Colorado Rockies (COLR) Biogeographical Area. Our research provides important ecological information of direct use to the US Global Change Research Program, Department of the Interior bureaus, and the public. For example, Tom Veblen's team completed a GIS map of fire history in over 30,000 hectares of subalpine forests in the southern two-thirds of Rocky Mountain National Park. He reported that years of widespread fire in the subalpine zone are limited to years of exceptional drought, which are statistically associated with La Niña events (i.e., the positive phase of the Southern Oscillation). La Niña events tend to be followed by dry springs in the northern Front Range. Contrary to popular belief, tree-ring reconstructions of spruce budworm outbreaks in Douglas fir forests show that outbreak frequency during the 20th century period of fire exclusion was not atypically high in comparison with the previous four centuries.

Baker's team found that a mixture of crown fires, mixed-severity fires, and surface fires occurred in the ponderosa pine forest of Rocky Mountain National Park prior to Euro-American settlement. However, quantitative targets for how frequent prescribed fires should be, how much land area should be burned in a particular year, or how much fuel reduction is appropriate, cannot be specified for restoration efforts because of large uncertainty in the pre-Euro-American fire regime. In addition, in spite of significantly changed climate since the middle 1800s, there is no compelling evidence at the present time that the alpine tundra zone in Rocky Mountain National Park is in danger of disappearing because of the upward movement of trees. Long-term monitoring of forest-tundra ecotones will be needed to detect significant movement in future years.

Stohlgren and Binkley's team found that elk herbivory did not greatly threaten populations of aspen and other native plant species in Rocky Mountain National Park and fears of such threats may have been exaggerated. Aspen regeneration is far greater and more widely distributed than previously measured, and understory species richness is very resilient to current patterns of herbivory. The cumulative effects of multiple stresses on biodiversity, the key focus of our research, suggests that invading non-native plants, animals, and diseases may be a far more urgent threat to native biodiversity in the coming decades and century compared to climate change. Combined with direct loss of key habitats associated with land use change, invasive species pose a significant and urgent challenge to land managers and policymakers.

Pielke's team showed that the spatial variability of greenness and land use is also implicated in the significant variation of long-term temperature data in eastern Colorado. The local teleconnection (over distances of tens to hundreds of kilometers) of weather effects from land-use change are now well documented, leading to a more integrated framework of climate variability and change.

Baron's team showed that increases of up to 4 degrees centigrade will change the timing, but not the amount of snowmelt runoff from high elevation watersheds. RHESSYs modeling of Loch Vale under GCM climate scenarios suggests warming over the next century could lead to more frequent low flow years. They also have found strong species response to climate (the elevation link) and to nitrogen concentrations (specifically for algae). This is important evidence that will be used as Rocky Mountain National Park decides whether to pursue air quality emissions regulations.

Rocky Mountain Futures: An Ecological Perspective was published in 2002 and reviews were excellent. The book summarizes the past, present, and future human disturbances to Rocky Mountain ecosystems, by giving background information on natural processes, a series of contemporary case studies, and syntheses of ecosystem integrity and environmental disturbances. The overwhelming conclusion is that the Rocky Mountains are today a profoundly human-influenced landscape, with few areas where natural processes dominate.

Overall, this project has produced 115 peer-reviewed publications, 15 reports, 76 presentations, 11 theses, and 9 dissertations in the past four years. The following final report details our specific accomplishments and our final deliverable products.

SPECIFIC ACCOMPLISHMENTS AND RESULTS

GIS-based disturbance history map of fire in subalpine forests to aid in Rocky Mountain National Park's Fire Management Program. – A GIS map of fire history in over 30,000 hectares of subalpine forests in the southern two-thirds of Rocky Mountain National Park was completed. We found that, within subalpine forests, the natural fire regime was dominated by stand-replacing fires killing most (> 90%) of canopy trees over areas of 1000s of hectares. In contrast, the total surface area determined to have had a history of non-lethal surface fires was less than 2%. Large areas of spruce-fir forest burn only at very long intervals (> 200 years) in association with extreme drought, often coinciding with La Niña events. The frequency and extent of burning during the post-1915 fire suppression period is not outside the historic range of variability of the past c. 400 years.

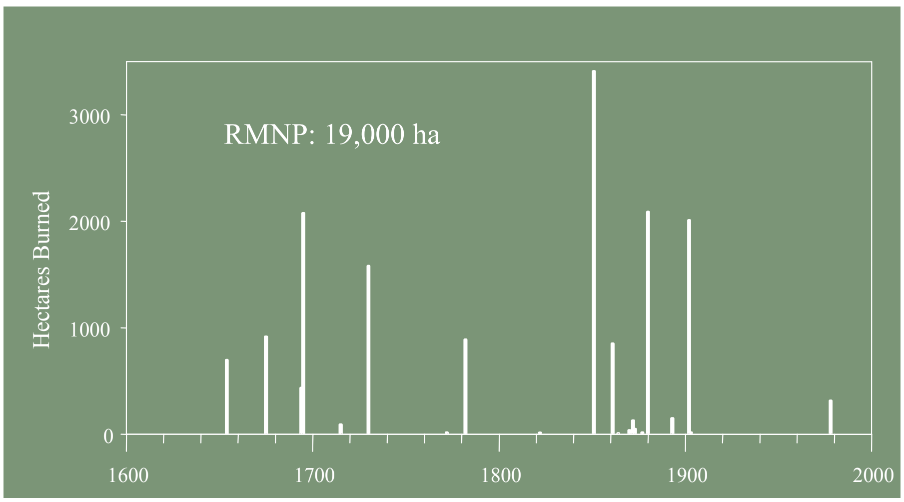


Figure 1: Fire history in subalpine forests of lodgepole pine and spruce fir. More than 30% of the subalpine zone has not burned in the last 400 years.

Relevance to resource managers: Our results show land managers and the public that extremely large fire events have occurred in this landscape in the past and that they are likely to occur again in the future in association with extreme drought. Our results show that modern fire suppression has not resulted in a landscape that departs significantly from the range of landscape conditions that occurred in the Park over the past c. 400 years. Fires in the subalpine zone were largely stand-replacing fires, and, consequently, proposals to mechanically thin subalpine forests to mimic a pre-settlement fire regime of widespread surface fires are not consistent with knowledge of the historic range of variability of these forests.

This study supports Question and Product: Q3,P3; Table – Feasibility of Milestones, Products, and Payoffs.

Climatic influences on fire and insect outbreaks in montane forests in the Front Range of Colorado. - We used tree rings to reconstruct the occurrence of fire and spruce budworm outbreaks in the montane forests of ponderosa pine and Douglas-fir in and nearby Rocky Mountain National Park in the Colorado Front Range. We found that within montane forests of the Park and surrounding areas, conditions for widespread fire are favored by drought and by high year-to-year variability in moisture availability statistically associated with El Niño-Southern Oscillation events. Spruce budworm outbreaks were associated with periods of above-average moisture availability and also with periods of high year-to-year variability in moisture availability during the growing season.

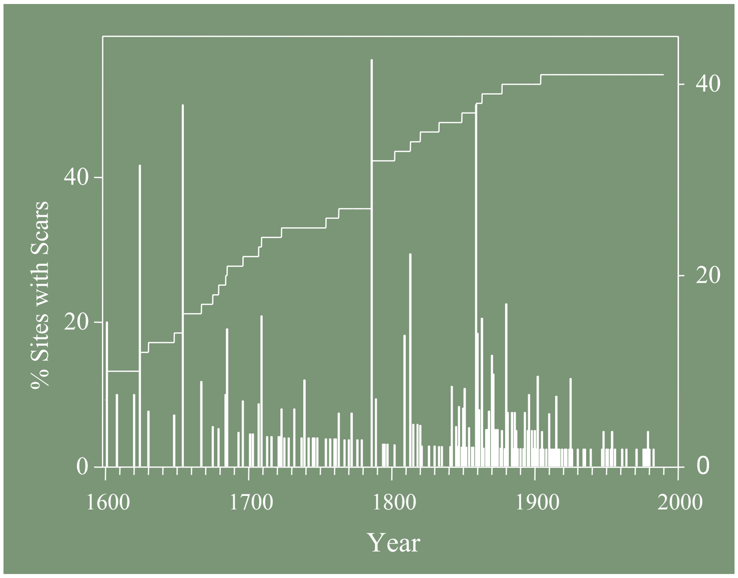


Figure 2: Increased burning in the late 19th century left a legacy of dense even-aged stands over much of the montane landscape of northern Colorado. This was primarily due to climate, but it was also due to Euro-American settlement.

Relevance to resource managers: The understanding of the relationships of major fire years to moisture variability associated with both the negative and positive phases of the El Niño-Southern Oscillation allows managers significant lead time to plan for years of extreme fire hazard. Based on our results, land managers can expect increased budworm activity during wetter decades and periods of high year-to-year variability in climate. Furthermore, the frequency of budworm outbreaks during the 20th century period of fire suppression is not significantly different from the previous 300 years, and such outbreaks should not be regarded as a departure from the historic range of variability.

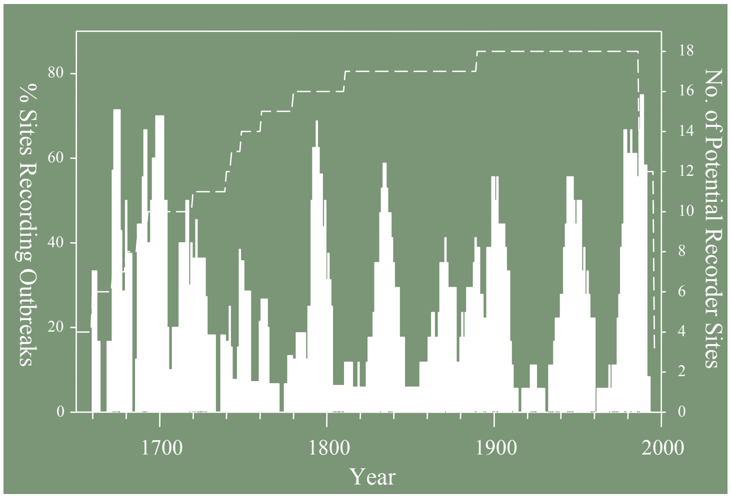


Figure 3: Regional spruce budworm activity in the southern and northern Front Range. These tree ring reconstructions show no recent increase in outbreaks.

This study supports Question and Product: Q2,P10; Table – Feasibility of Milestones, Products, and Payoffs.

<u>How fires and suppression affect ponderosa pine densities.</u> – Fires vary in severity of low, mixed, and high-severity fires. Tree regeneration follows fires of different severities, especially high-severity fires. High density of trees after high-severity fires is a natural mode of regeneration (up to 3,000 trees/ha). Fire suppression since Euro-American settlement has led to decreased tree regeneration and mortality. Therefore, restoring fire would likely increase density of small trees and so increase ladder fuels.

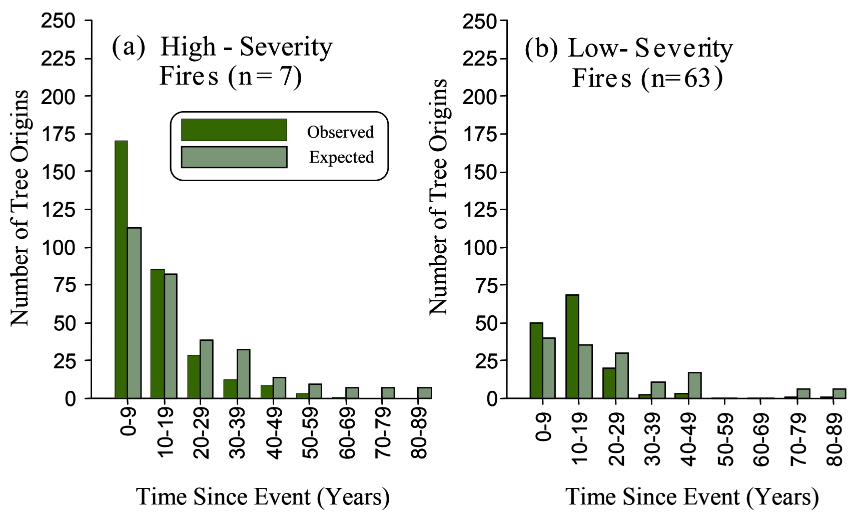


Figure 4: Tree regeneration following low and high-severity fire in ponderosa pine stands of Rocky Mountain National Park.

Relevance to resource managers: As managers seek to restore fire to previously fire-suppressed ecosystems, it is important to know the consequences of such actions. This study has shown that restoring fires would likely increase the density of small ponderosa pine trees, thereby increasing ladder fuels and the possibility of high-severity crown fires.

This study supports Question and Product: Q3,P3; Table – Feasibility of Milestones, Products and Payoffs.

<u>The historic range of variability in the fire regime of ponderosa pine stands within Rocky Mountain National Park.</u> – A mixture of crown fires, mixed-severity fires, and surface fires occurred in the ponderosa pine forests of Rocky Mountain National Park prior to Euro-American settlement. Therefore, thinning (e.g., mechanical, prescribed burns) of these forests, the removal of dead trees and downed wood, and other programs to lower the risk of mixed or high-severity fires in ponderosa pine forests may satisfy sociopolitical objectives, but should not be labeled as restoration. Longer fire rotations and spatially patchy fires also suggest that a greater diversity of forest structures probably existed in the pre-Euro-American ponderosa pine landscape, possibly leading to some crown fires. Dense thickets of regenerating trees or dense old patches of trees may have been a part of the ponderosa pine forest landscape at that time.

Relevance to resource managers: A historic range of variability in fire regimes is needed for managers using fire as a restoration practice. Although it is known that a mixture of crown fires, mixed-severity fires, and surface fires occurred in the ponderosa pine forests of the Park prior to Euro-American settlement, quantitative targets for how frequent prescribed fires should be, how much land area should be burned in a particular year, or how much fuel reduction is appropriate cannot be specified for restoration efforts because of large uncertainty in the pre-Euro-American fire regime. Managers of parks and adjoining areas may have a difficult task given the natural spatial and temporal variability within these forests.

This study supports Question and Product: Q3,P3; Table – Feasibility of Milestones, Products and Payoffs.

<u>The treeline environment and how it has been affected by climate change.</u> – Below treeline, there is abundant tree regeneration in subalpine meadows interspersed with patches of subalpine trees, and this regeneration dates primarily to a warm, wet period in the 1950s and 1960s. There is also significant change in growth form near treeline, where krummholz growth forms have grown up to become tree height. This height growth occurred in a continuous process since the middle-1800s, a period associated with warmer and wetter conditions since the end of the Little Ice Age. There is no present evidence of abundant tree regeneration in alpine tundra, although scattered clumps of small trees occur. Our data suggest that it is possible that if warming continues without significant increases in precipitation, tree regeneration will not necessarily be favored in tundra or in subalpine meadows because this regeneration was favored only during warm and wet conditions in the past.

Relevance to resource managers: In spite of significantly changed climate since the middle 1800s, there is no compelling evidence at the present time that the alpine tundra zone in Rocky Mountain National Park is in danger of disappearing because of the upward movement of trees. Managers may wish to monitor the treeline environment by setting up permanent photographic points, but our work suggests that these points need to only be observed and evaluated approximately every 25 years to be able to detect significant movement in the forest-tundra ecotone.

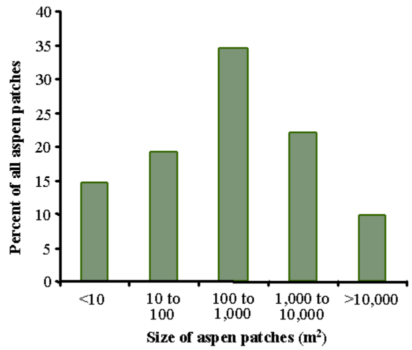
This study supports Question and Product: Q3,P2; Table – Feasibility of Milestones, Products and Payoffs.

<u>Determine how climate change, vegetation management practices, and disturbance affect the spread of non-native plants.</u> – Non-native plant species have systematically invaded rare habitat types and lowland mesic areas in Rocky Mountain National Park and elsewhere. However, only a small percentage of non-native plant species are invasive, and only a small portion of the Park is heavily invaded. In addition, species traits of successful invaders are far less predictable than the vulnerability of habitats to invasion. Fire suppression in forests may suppress invasions by non-native plant species indirectly with increased canopy cover, but post-wildfire habitats are particularly vulnerable to plant invasions. The interactions between climate, fire, and plant invasions will help develop better predictive spatial models for the early detection and rapid response of non-native plants.

Relevance to resource managers: The cumulative effects of multiple stresses on biodiversity suggests that invading plants, animals, and diseases may be a far more urgent threat to native biodiversity in the coming decades and century compared to climate change. Combined with direct loss of key habitats associated with land use change, invasive species pose a significant and urgent challenge to land managers and policymakers.

This study supports Question and Product: Q2,P6; Table – Feasibility of Milestones, Products and Payoffs.

<u>Determine how climate change, vegetation management practices, and disturbance affect aspen regeneration.</u> – About half of the aspen in the Front Range of Colorado is found in patches smaller than 200 m^2, which have been largely overlooked in previous studies that had larger minimum mapping units. Thus, aspen regeneration is far greater and more widely distributed than previously measured. Aspen regeneration has been relatively strong in recent decades, except in the areas of the heaviest winter-time use by elk (where little to no regeneration has been successful), but it appears that understory species richness is very resilient to current patterns of herbivory. Conifer invasion and competition have more severe effects on aspen regeneration (especially preventing it) than on aspen growth.



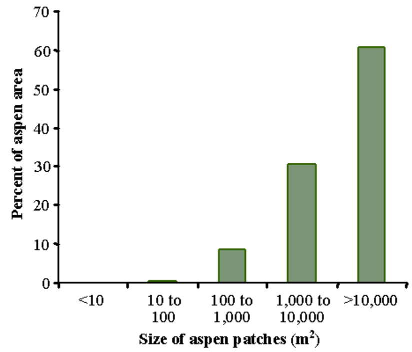


Figure 5: Aspen patches ranged in size (left) from less than 10 m^2 to more than 1 hectare (10,000 m^2), but the most common patch size was 100 to 1000 m^2. Although most patches of aspen were small, the large patches of aspen comprised the majority of the total cover of aspen in the Park (right); more than half the total aspen area was found in patches > 1 ha in size.

Relevance to resource managers: Contrary to some reports, aspen forests are not in immediate threat of disappearance from the central Rockies. Opportunities for enhancing aspen on the landscapes include reducing the intensity of winter-time elk use in high-density areas, and reducing conifer dominance through increased fire or other disturbances.

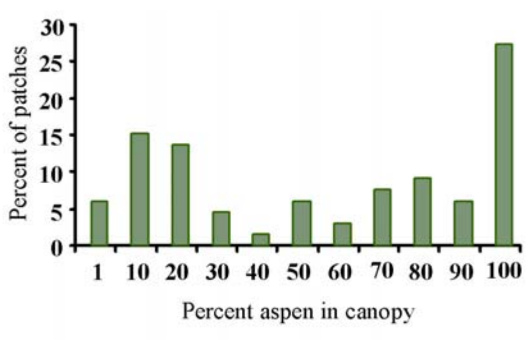


Figure 6: Aspen trees are commonly mixed with conifers; only about one-quarter of aspen trees are found in stands with no conifers (where aspen accounts for 100% of the canopy).

This study supports Question and Product: Q3,P3; Table – Feasibility of Milestones, Products and Payoffs.

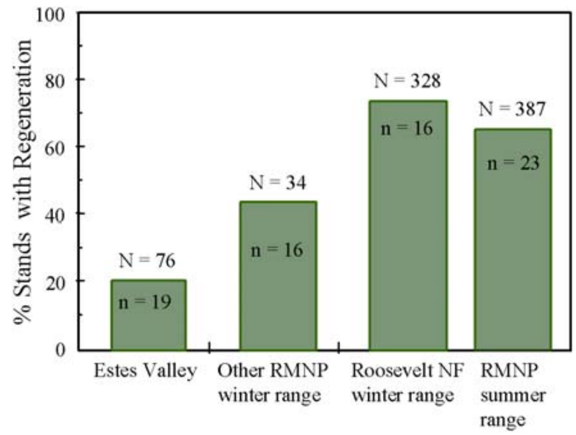


Figure 7: Percent of aspen stands with a successful young cohort (> 2m tall) in the past 20 years. N=number of stands mapped from photos; n = number of stands sampled.

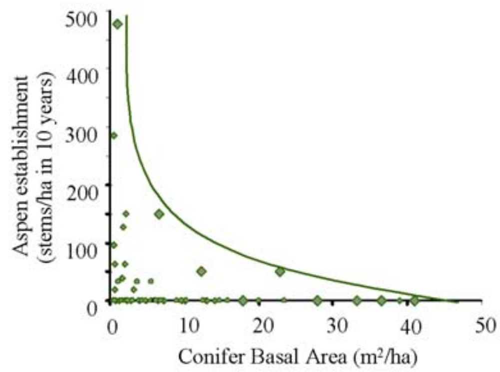


Figure 8: Number of aspen regenerating in a ha for each 10 year period as a function of conifer basal area. A conifer basal area of 10 m^2/ha equals about 50 trees with a 15 cm diameter.

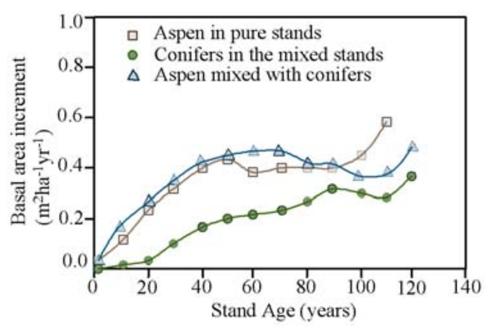


Figure 9: Aspen basal area growth appeared to be unaffected by the presence of understory conifers.

<u>The productivity of old-growth forests and how it is related to stand structure and environmental resource supplies.</u> – Overall, the structure of old-growth forests (including the size of the forest canopies) had a greater influence on forest growth than did the supply of nutrients, light, or water. We now expect that the response of old-growth forests in the Rockies to changing climate will depend less on the direct environmental changes (such as precipitation) and more on the changing timing and severity of disturbances that develop stand structure. Future rates and intensities of disturbances will be the key driver in the fate of old-growth forests in the Rocky Mountains, probably much more important than direct effects of temperature or precipitation changes.

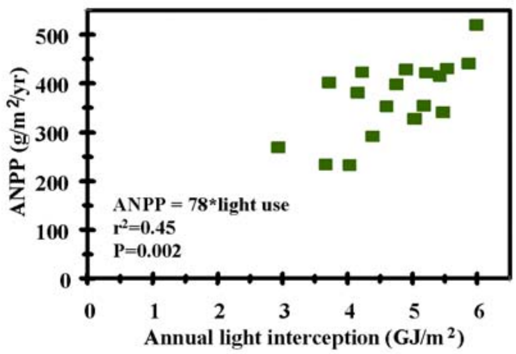


Figure 10: Production in 18 old-growth spruce/fir forests related strongly to the amount of light captured by tree canopies.

Relevance to resource managers: Under a changing climate, it is important for resource managers to know what the consequences of global change will be to a particular system. This study found that increased disturbances that affect stand structure will have the most impact on old-growth forests that dominate much of the subalpine landscape of the Central Rocky Mountains.

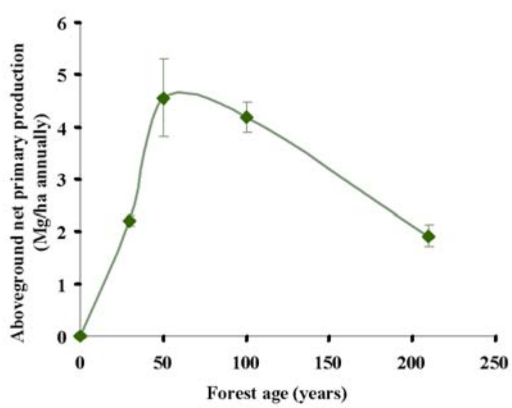


Figure 11: Aboveground production peaked near age 50 in an age sequence of lodgepole pine forests, declining by more than half by age 200. Error bars are standard deviations among replicate stands.

This study supports Question and Product: Q2,P2; Table – Feasibility of Milestones, Products and Payoffs.

Provide better climate change scenarios to land managers to assess the vulnerabilities of ecosystems to rapid environmental change. – We documented the significant role of vegetation greenness on maximum and minimum temperatures in northeastern Colorado, and found that greenness is directly affected by irrigation and previous precipitation. The spatial variability of greenness and land use is implicated in the significant variation of long-term temperature data in eastern Colorado. Through this research, it was shown how snow cover and lack of snow cover substantially influence temperature and atmospheric dispersion. The local teleconnection (over distances of tens to hundreds of kilometers) of weather effects from land-use change are now documented, dictating the need for an integrated framework of climate variability and change.

Relevance to resource managers: Among our most significant accomplishments is that we have shown that the assessment of vulnerability of resources to climate and environmental variability and change is more comprehensive and useful to policymakers than a limited modeling based prediction of future conditions. The use of historical- and paleo- records of past environmental conditions (such as drought), but with the today's and expected future human residence in a region, provides a particularly robust approach to assess vulnerability.

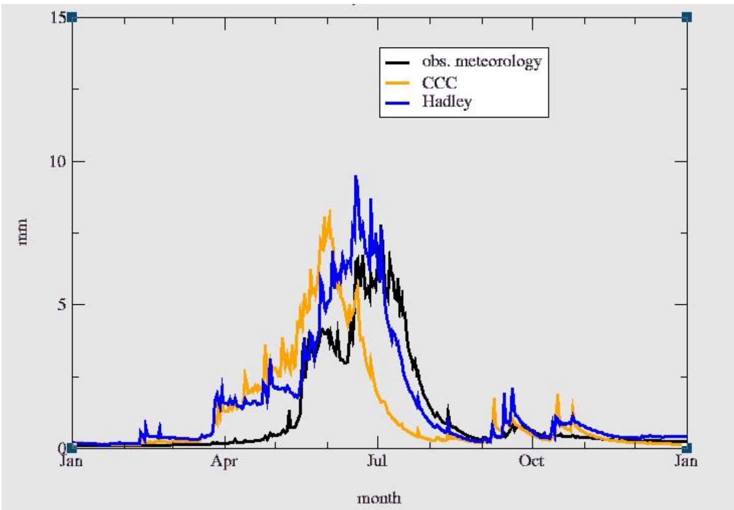
This study supports Question and Product: Q2,P9; Table – Feasibility of Milestones, Products and Payoffs.

Evaluating regional and local trends in temperature within eastern Colorado: - Many climate change studies tend to generalize regional patterns by examining data from single stations, single seasons, or a few parameters over a short time scale by averaging data from dissimilar stations or by using coarse-scale general circulation models. Therefore, we explored the potential shortcomings of these studies by evaluating long-term trends in average maximum and minimum temperatures, threshold temperatures, and growing season in eastern Colorado. This study found that finer-scale spatial and temporal variation must be considered when evaluating climate change because of the improbability that a few weather stations represent regional climate trends or that coarse-scale general circulation models will accurately portray trends at subregional scales.

Relevance to resource managers: This study provides a reasonable robust procedure to evaluate climate trends and variability by assessing a group of weather stations for consistent, more qualitative trends.

This study supports Question and Product: Q2,P9; Table – Feasibility of Milestones, Products and Payoffs.

Mountain hydrologic and ecosystem responses to climate scenarios. – These climate scenarios have been addressed with the RHESSys (Regional HydroEcological Simulation System) model, which is a series of ecosystem and hydrologic models run on a GIS platform. Climate change scenarios for Loch Vale watershed (a mostly unvegetated catchment at the highest elevations) and Big Thompson watershed (85% forested) strongly suggest that hydrology is directly related to winter precipitation amounts. For the Big Thompson watershed, streams are fed by snow that accumulates high above treeline in mountain basins, and precipitation to the east-facing slopes is used for evapotranspiration instead of stream flow. Temperature changes mostly affect the timing of snowmelt, but when winter and spring temperature warm to 4^{o}C, snowmelt begins to occur throughout the winter, leading to strong changes in soil moisture (and thus nutrient cycling), snowpack duration, and primary productivity. In addition, RHESSYs modeling of Loch Vale under GCM climate scenarios suggests that if warming over the next century occurs, this could lead to more frequent low flow years.



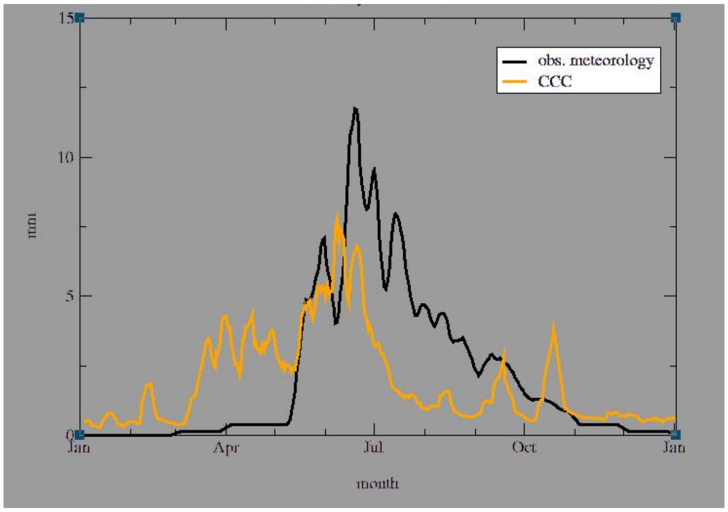


Figure 12: 1993 RHESSys streamflow models for BigThompson (top) and Loch Vale (bottom) watersheds. Timing of snowmelt is dependent on temperature.

Relevance to resource managers: Ecosystem models are the only way to forecast future ecological and hydrological conditions, but when built upon long-term measurements and understanding of ecosystem processes, they present plausible scenarios that managers can use to prepare and plan for. Our modeling efforts over the past eight years have shown the potential for climate change to drastically change the timing of spring snowmelt runoff, affecting regional water supply. They have also highlighted possible changes to vegetation under climate change scenarios and the potential for extended periods of prolonged drought if GCM scenarios come about.

This study supports Question and Product: Q2,P10; Table – Feasibility of Milestones, Products and Payoffs.

Effects of nitrogen deposition on high elevation terrestrial and aquatic systems. – We have found significant differences in nitrogen cycling in both forests and lakes that are due to high N deposition east of the continental divide (from transportation, agricultural, and industrial emissions), compared with much lower N deposition west of the divide. Both the accumulation of N in forest soils and the change in aquatic algal communities (from paleolimnological analyses) tell us the changes began between 1950 and 1960, coincident with increases in human and livestock populations to the South Platte River Basin. Although changes to forest plant communities are not apparent, there are strong increases in soil microbial activity and foliar N concentrations. Algal communities have changed dramatically in east-side lakes, and now represent mesotrophic conditions, instead of the oligotrophic communities found in west-side lakes and in lake sediments prior to 1950. Algal community rates of change show west-side lakes are changing slowly, possibly in response to slight increases in regional N deposition, and not nearly as rapidly as east-side lakes.

Relevance to resource managers: Our nitrogen biogeochemistry work over the years has provided a wealth of information to Rocky Mountain National Park and regional national forest managers. We have shown significant changes to soil N storage, microbial activity, forest nutrient cycling, aquatic ecosystems, and lake chemistry. We have identified upward trends in N deposition along the Colorado Front Range, and the origin of their emissions. Managers have carefully used these data to alert EPA and State air quality officials of their concern that N emissions may be in violation of the NPS and USDA FS Clean Air Act Amendment and Wilderness Act requirements to maintain air quality.

This study supports Question and Product: Q2,P5; Table – Feasibility of Milestones, Products and Payoffs.

Human-driven change to the entire Rocky Mountain chain. – The overwhelming conclusion of *Rocky Mountain Futures, an ecological perspective* is that the Rocky Mountains are today a profoundly human-influenced landscape, with few areas where natural processes dominate. Most regions have a history of accumulated human impact that has eroded native species assemblages and altered natural rejuvenating processes such as flooding and fire. The trend toward increasing disruption of the natural environment continues rapidly today, due to lack of regional planning and land use change. Without vision of what the Rocky Mountain environment should look like in 50-100 years, there will be no region left where natural ecosystems persist without massive management intervention. There are a few areas, however, where restoration, remediation, and protection are occurring and these should be used as models for the rest of the Rocky Mountains.

Relevance to resource managers: This book has begun to be a catalyst for planners, managers, and regional citizens to change how we view and act on the landscapes, processes, and ecosystems that make the Rockies unique. Book reviews have been quite favorable, but more importantly, the message from the book has been in great demand, augmenting a growing regional momentum to act in order to direct future environmental conditions in the Rocky Mountains. Rocky Mountain National Park, along with the Arapaho-Roosevelt Forest, is developing a task force to produce future scenarios under different management and climate scenarios that will be presented to decision makers in the future. Similar plans are beginning in the Southern Rockies as part of the Southern Rockies Ecosystem Project and Wildlands Initiative, as well as through Colorado College. USGS is moving forward with stakeholder-driven establishment of Indicators of Condition for the Colorado Front Range through the Science Impact program.

This study supports Question and Product: Q3,P1; Table – Feasibility of Milestones, Products and Payoffs.

PRODUCTS

Data Sets

Tom Stohlgren, Principal Investigator
Data available at:
http://www.nrel.colostate.edu/projects/stohlgren/_projects/gcts2.html
Supports Question and Product: Q2,P6; Q3,P3; Table-Feasibility of Milestones, Products, and Payoffs.

William L. Baker, Principal Investigator
No data sets are available.

Jill Baron, Principal Investigator
Loch Vale Watershed Research Project Data available at:
http://www.nrel.colostate.edu/projects/lvws/pages/accesstodata/accesstodata.htm
National Atmospheric Deposition Program Data available at:
http://nadp.sws.uiuc.edu/ (site number CO98)
Supports Question and Product: Q2,P5; Q2,P10; Table-Feasibility of Milestones, Products, and Payoffs.

Dan Binkley, Principal Investigator
BinkleyOldGrowthConifer.xls. Contains data on tree species, numbers, diameter, leaf area, growth and biomass for old forests in Rocky Mountain National Park, and adjacent Neota Creek Wilderness. Data set is complete, not documented in any database. Available at:
http://www.nrel.colostate.edu/projects/stohlgren/_projects/gcts2.html.
Supports Question and Product: Q2,P2; Table-Feasibility of Milestones, Products, and Payoffs.

BinkleyExclosureNSupply.xls. Contains data on net N mineralization and resin-bag N for old and young exclosures in and near Beaver Meadows in Rocky Mountain National Park. Data set is complete, not documented in any database. Available at:
http://www.nrel.colostate.edu/projects/stohlgren/_projects/gcts2.html.
Supports Question and Product: Q2,P2; Table-Feasibility of Milestones, Products, and Payoffs.

BinkleyOldExclosureSoil.xls. Contains data on soil bulk density, total N and C, and available cations and phosphorus for the 3 old exclosures in Beaver Meadows in Rocky Mountain National Park. Data set is complete, not documented in any database. Available at:
http://www.nrel.colostate.edu/projects/stohlgren/_projects/gcts2.html.
Supports Question and Product: Q2,P2; Table-Feasibility of Milestones, Products, and Payoffs.

BinkleyRMNPAspenAges.xls. Contains data on tree numbers, diameters, and ages for pure aspen stands in Rocky Mountain National Park and Roosevelt National Forest.

Data set is complete, not documented in any database. Available at: http://www.nrel.colostate.edu/projects/stohlgren/_projects/gcts2.html.
Supports Question and Product: Q3,P3; Table-Feasibility of Milestones, Products, and Payoffs.

Timothy G.F. Kittel, Principal Investigator
No data sets are available.

Roger A. Pielke, Sr., Principal Investigator
No data sets are available.

Tom Veblen, Principal Investigator
Fire-scar data set.
The fire-scar data set is currently in progress for submission to the International Multiproxy Paleofire Database, NOAA. The contact person is T. Veblen, Geography, CU-Boulder. After September 1, 2004 the fire-scar data may be accessed at: http://www.ngdc.noaa.gov/paleo/impd/
Supports Question and Product: Q3,P3; Q2,P10; Table-Feasibility of Milestones, Products, and Payoffs.

Fire history map data set.
The GIS map of fire history of the southern two-thirds of Rocky Mountain National Park is in progress. It will be submitted to the Park by July 2005. In the meantime the contact person is T. Veblen, Geography, CU-Boulder.
Supports Question and Product: Q3,P3; Table-Feasibility of Milestones, Products, and Payoffs.

Tree-ring data set on insect pest outbreaks.
The tree-ring data set on insect pest outbreaks is in progress for submission to the International Tree-ring Data Archive, NOAA. Currently, the contact person is T. Veblen, Geography, CU-Boulder.
Supports Question and Product: Q2,P10; Table-Feasibility of Milestones, Products, and Payoffs.

Reports, Abstracts, and Presentations

Reports:

Allstott, E.J., M. Bashkin, and J.S. Baron. 2000. Loch Vale Watershed Project Quality Assurance Report: 1995-1998: U.S. Geological Survey Open-File Report 99-111. Fort Collins, CO: Natural Resource Ecology Laboratory, Colorado State University. 48 p.

Baker, W.L., and D.S. Ehle. In Press. Uncertainty in fire history and restoration of ponderosa pine forests in the western United States. Proceedings of the Conference on Fire, Fuel Treatments, and Ecological Restoration: Proper Place, Appropriate Time. USDA Forest Service Proceedings XXXX. Fort Collins, CO: Rocky Mountain Research Station.

Binkley, D., F.J. Singer, M. Kaye, and R. Rochelle. 2002. Influence of elk grazing on soil and nutrients in Rocky Mountain National Park. In: Singer, F.J., and L.C. Zeigenfuss, editors. Ecological evaluation of the abundance and effects of elk herbivory in Rocky Mountain National Park, 1994-1999. Fort Collins, CO: U.S. Geological Survey Open Report 02-208. p Chapter 10.

Burns, D.A. 2002. The effects of atmospheric nitrogen deposition in the Rocky Mountains of Colorado and Southern Wyoming-a synthesis and critical assessment of published results. Water-resources-investigations report 02-4066. Troy, NY: U.S. Geological Survey.

Chong, G.W., S.E. Simonson, T.J. Stohlgren, and M.A. Kalkhan. 2001. Biodiversity: Aspen stands have the lead, but will non-native species take over? In: Shepperd, W.D., D. Binkley, D.L. Bartos, T.J. Stohlgren, and L.G. Eskew, editors. Sustaining Aspen in Western Landscapes: Symposium Proceedings; 13-15 June 2000; Grand Junction, CO. Proceedings RMRS-P-18. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. p 460.

Grace, J.B., M. Smith, S.L. Grace, S. Collins, and T.J. Stohlgren. 2001. Interactions between fire and invasive plants in temperate grasslands in North America. In: Galley, K., and T. Wilson, editors. Fire Conference 2000: The First National Congress on Fire, Ecology, Prevention and Management. Invasive Species Workshop: The Role of Fire in the Control and Spread of Invasive Species. Tall Timbers Research Station, Miscellaneous Publication No. 11. p 40-65.

Kaye, M., K. Suzuki, D. Binkley, and T.J. Stohlgren. 2001. Landscape-scale dynamics of aspen in Rocky Mountain National Park, Colorado. In: Shepperd, W.D., D. Binkley, D.L. Bartos, T.J. Stohlgren, and L.G. Eskew, editors. Sustaining Aspen in Western Landscapes: Symposium Proceedings; 13-15 June 2000; Grand Junction, CO. Proceedings RMRS-P-18. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. p 39-46.

Keane, R.E., K.C. Ryan, T.T. Veblen, C.D. Allen, J. Logan, and B. Hawkes. 2002. Cascading effects of fire exclusion in Rocky Mountain ecosystems: A literature review. USDA Forest Service General Technical Report RMRS-GTR-91. 24 p.

Pielke Sr., R.A., and T.N. Chase. 2003. A proposed new metric for quantifying the climatic effects of human-caused alterations to the global water cycle. Preprints, Symposium on Observing and Understanding the Variability of Water in Weather and Climate, 83rd AMS Annual Meeting, February 9-13, Long Beach, CA.

Reiners, W.A., W.L. Baker, J.S. Baron, D.M. Debinski, S.A. Elias, D.B. Fagre, J.S. Findlay, L.O. Mearns, D.W. Roberts, T.R. Seastedt, T.J. Stohlgren, T.T. Veblen, and F.H. Wagner. 2003. Natural Ecosystems I: the Rocky Mountains. In: Wagner, F.H., editor. Preparing for Climate Change: Rocky Mountain/Great Basin Regional Climate Change Assessment, a report of the Rocky Mountain/Great Basin regional assessment team for the U.S. Global Change Research Program. Logan, UT: Utah State University. p 240.

Shepperd, W.D., D. Binkley, D.L. Bartos, T.J. Stohlgren, and L.G. Eskew. 2001. Sustaining Aspen in Western Landscapes: Symposium Proceedings. 13-15 June 2000; Grand Junction, CO. Proceedings RMRS-P-18. Fort Collins, CO: US Department of Agriculture, Forest Service, Rocky Mountain Research Station. 406 p.

Stohlgren, T.J. 1999a. Global change impacts in nature reserves in the United States. In: Aguirre-Bravo, C., and C.R. Franco, editors. Proceedings of the North American Symposium Toward a Unified Framework for Inventory and Monitoring Forest Ecosystem Resources. Fort Collins, CO: USDA Forest Service Rocky Mountain Forest and Range Experiment Station General Technical Report RMRS-P-12. p 5-9.

Stohlgren, T.J. 1999b. Measuring and monitoring biodiversity in forests and grasslands in the United States. In: Aguirre, C., and C.R. Franco, editors. Proceedings of the North American Symposium Toward a Unified Framework for Inventory and Monitoring Forest Ecosystem Resources. Fort Collins, CO: USDA Forest Service Rocky Mountain Forest and Range Experiment Station General Technical Report RMRS-P-12. p 248-255.

Veblen, T.T. 2003. Key issues in fire regime research for fuels management and ecological restoration. In: Omi, P., and L. Joyce, editors. Fire, Fuel Treatments, and Ecological Restoration: Conference Proceedings: 2002 16-18 April. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. p 259-276.

Wagner, F.H., editor. 2003. Rocky Mountain/Great Basin Regional Climate Change Assessment. A Report of the Rocky Mountain/Great Basin Regional Assessment Team for the U.S. Global Change Research Program. Logan, UT: Utah State University. 240 p.

Presentations:

Sibold, J. 2004. Rocky Mountain National Park Research Conference, Estes Park, CO, "Surface fire and mountain pine beetle impacts on lodgepole pine forest stand structure".

Sibold, J. and **T.T. Veblen**. 2004. Association of American Geographers Annual Conference, Philadelphia, PA, "Multi-scale influences on fire regimes in subalpine forests in Rocky Mountain National Park, Colorado".

Sherriff, R.L. and **T.T. Veblen**. 2004. Predicting areas of different fire regime types in ponderosa pine forests of northern Colorado. Oral presentation at the AAG 2004

Conference, Philadelphia, PA.

Baron, J.S. Denver Zoo (Southern Rockies Ecosystem Project, Feb 2004).

Baron, J.S. High Altitude Revegetation seminar, Ft Collins March 2004.

Baron, J.S. Univ. Montana seminar, March 2004.

Baron, J.S. Boulder Watershed Forum March 2004.

Baron, J.S. Federal Land Managers Critical Loads workshop, Denver March 2004.

Binkley, D. Drivers of age-related decline in forest growth. Workshop on spatial and temporal patterns in old-growth forests (March 22-24, 2004, HJ Andrews Experimental Forest, Oregon).

Binkley, D. Aspen in the Colorado Rockies: Current status and future trends. CanFor lecture series (March 8-9, 2004, University of Northern British Columbia, Prince George).

Baron, J.S. Rocky Mountain Futures Forum, Rocky Mountain National Park April 2004.

Baron, J.S. Rocky Mountain Report Card, Colorado College, May 2004.

Baron, J.S. University of Denver seminar May 2004.

Sibold, J. 2003. Rocky Mountain National Park Monthly Program, Grand Lake, CO, "Subalpine Forest Fire History, Rocky Mountain National Park, Colorado".

Sibold, J. 2003. Rocky Mountain National Park Saturday Night at the Park, Estes Park, CO, "Fire and insect impacts on lodgepole pine forest stand structure".

Sibold, J. 2003.Rocky Mountain National Park Saturday Night at the Park, Estes Park, CO, "Subalpine Forest Fire History, Rocky Mountain National Park, Colorado".

Nydick, K.R. 2003. The role of nitrogen in high elevation lakes. Aquatic, Watershed, and Earth Resources Department seminar, Utah State University, Jan. 27, Logan, UT.

Pielke, R.A. Sr., and T.N. Chase. 2003: A proposed new metric for quantifying the climatic effects of human-caused alterations to the global water cycle. 2003 AMS Annual Meeting, Symposium on Observing and Understanding the Variability of Water in Weather and Climate, 9-13 February, Long Beach, CA.

Binkley, D. Understanding How Forests Grow – 25 years on the Ecology of Forest Production. Distinguished Ecologist Lecture Series (October 10, 2003, Michigan Technological University, Houghton).

Binkley, D. Ecology of Aspen in Rocky Mountain National Park: Effects of elk browsing and conifer invasion. Merriam/Powell Center Lecture Series (November 10, 2003, Northern Arizona University, Flagstaff).

Baron, J.S. EPA Region 8 May 2003.

Binkley, D., M. Kaye, K. Suzuki, and **T.J. Stohlgren**. Ecology of Aspen in Rocky Mountain National Park: Effects of elk browsing and conifer invasion. IUFRO Conference on Economic and Ecologic Benefits of Mountain Forests (September 16-20, 2003, Innsbruck, Austria).

Baron, J. Gore Range Natural Science School, July 2003.

Stohlgren, T.J., D.T. Barnett, C.H. Flather, P. Fuller, J. Kartesz. Species diversity and the patterns of invasion of multiple biological groups in the United States. August, 2003 in Savannah, Georgia. (PRESENTED)

Nydick, K.R., C. Arp, M. Baker, R. Hall, and W. Wurtsbaugh. 2003. Comparative retention of nitrogen in stream-lake linkages during snowmelt. Ecological Society of America (ESA) Annual Meeting, Aug. 3-8, Savannah, GA.

Baron, J.S. Aspen Wilderness Workshop, September 2003.

Sherriff, R.L., **T.T. Veblen**, and J.S. Sibold. 2002. Fire history at high elevation in the Colorado Front Range. Oral presentation at the AAG Conference, Los Angeles, CA. Best Ph.D. Student Paper Award, Biogeography Specialty Group.

Hicke, J.A., G.P. Asner, R.L. Sherriff, and **T.T. Veblen**. 2002. Using dendroecology to assess the impact of forest encroachment on the carbon budget. Poster Presentation, Ecological Society of America (ESA) Conference, Tucson, Arizona.

Stohlgren, T.J., Schnase, J.L., R.M. Reich, M.A. Kalkhan and J.A. Smith. Next-generation spatial modeling for ecological forecasting. Ecological Society of America Meetings in Tucson, Arizona (August 4-9, 2002). (PRESENTED)

Nydick, K.R., B.M. Lafrançois, **J.S. Baron**, and B.M. Johnson. 2002. Nitrogen cycling and biological alkalinity production following nutrient and acid additions to mountain lakes. Ecological Society of America (ESA) Annual Meeting, Aug. 4-9, Tucson, AZ.

Alley, T., N.W., R.O. Coleman, **T.J. Stohlgren**, P.H. Evangelista, and D.A. Guenther. Integrating various data layers and multi-media in a comprehensive format for land managers: A case study at Grand Staircase-Escalante National Monument, Utah. Ecological Society of America Meetings in Tucson, Arizona (August 4-9, 2002).

Chong, G.W., M.A. Kalkhan, R.M. Reich and **T.J. Stohlgren**. From points to landscapes: regression tree analysis and estimates of species richness. Ecological Society of America Meetings in Tucson, Arizona (August 4-9, 2002).

Simonson, S.E., D.T. Barnett, **T.J. Stohlgren** and A. Randell. Dataset integration and information sharing for improved prediction and detection of harmful invasive species. Ecological Society of America Meetings in Tucson, Arizona (August 4-9, 2002).

Stohlgren, T.J., M.A. Kalkhan, D.T. Barnett and S.E. Simonson. Beyond theory: lessons from natural landscapes. Ecological Society of America Meetings in Tucson, Arizona (August 4-9, 2002). (PRESENTED)

Kalkhan, M.A., P.N. Omi, E.J. Martinson, **T.J. Stohlgren**, G.W. Chong and M.A. Hunter. Invasive plants and wildfire on the Cerro Grande fire, Los Alamos: Integration of spatial information and spatial statistics. Ecological Society of America Meetings in Tucson, Arizona (August 4-9, 2002).

Kaye, M.W., **D. Binkley** and **T.J. Stohlgren**. Conifer invasion of quaking aspen stands in Rocky Mountain National Park, Colorado. Ecological Society of America Meetings in Tucson, Arizona (August 4-9, 2002).

Sibold, R.L. 2001. Presentation at the Fuels Mapping Management Meeting, Rocky Mountain National Park, Estes Park, Colorado.

Sibold, R.L. 2001. Presentation to the Fire Management Staff of Rocky Mountain National Park, Estes Park, Colorado.

Donnegan, J. and **T.T. Veblen**. 2001. Fire history in Pike National Forest. Paper presented at the annual meeting of the Association of American Geographers.

Sherriff, R.L., **T.T. Veblen**, and J.S. Sibold. 2001. Fire history in high elevation subalpine forests in the Colorado Front Range. Poster Presenter at the Ecological Society of America (ESA) Conference, Madison, Wisconsin.

T.T. Veblen. 2001. Changes in Fire Regimes in the Colorado Front Range Since c. 1700 A.D. Paper presented to Facing Fire: Lessons from the Ashes, Center of the American West, Feb. 2001.

Nydick, K., B. Moraska, **J. Baron**, B. Johnson. 2001. Mesocosm experiments to determine if subtle nitrogen additions can alter primary production in small mountain lakes, Snowy Range, WY. American Society of Limnology and Oceanography (ASLO) Annual Meeting, Feb 11-16, Albuquerque, NM.

T.T. Veblen. 2001. Fire history in the Colorado Front Range. Paper presented at the Colorado Fire Conference, Longmont, March, 2001.

Simonson, S., G. Chong, **T. Stohlgren**. "Invasive Alien Plant Species Threaten Native Plants and Butterflies in Rocky Mountain National Park," at the sixth meeting of the Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA), held in Montreal, Canada from March 12 to 16, 2001.

Nydick, K., B. Moraska, **J. Baron**, B. Johnson. 2001. Simulation of N deposition to small mountain lakes, Snowy Range, WY. Front Range Student Ecology Symposium, March 14-15, Fort Collins, CO.

T.T. Veblen. 2001. Fire history and forest changes in the Colorado Front Range. Talk presented to the Boulder Chapter of the Society for Conservation Biology, Boulder, July 2001.

Nydick, K.R. 2001. Aquatic Ecology at 10,500 ft.: Research with an Altitude! Canon Envirothon - North American Environmental Science Competition for High School Students, July 25-29, Hinds Community College, MS.

Nydick, K., B. Moraska, **J.S. Baron**, J. Sickman, and B. Johnson. 2001. Sensitivity of western mountain lakes to N deposition. Symposium on N deposition in the West, Ecological Society of America (ESA) Annual Meeting, Aug. 6-10, Madison, WI.

N.L. Stephenson, T.W. Swetnam and **T.T. Veblen**. 2000. Altered disturbance regimes: fire, fuels, and forest structure. Paper presented to the annual meeting of the Ecological Society of America, Snowbird, Utah.

Sherriff, R.L. 2000. Fire and climatic variation in the subalpine forests in northern Colorado. Oral presenter at the Western Geography Student Conference, University of Colorado, Boulder.

Kitzberger, T. and **T.T. Veblen**. 2000. Fire histories in conifer woodlands of Northern Patagonia and the central Rocky Mountains. Paper presented to the quintennial meeting of the International Association for Tree-Ring Research, Mendoza, Argentina.

Kalkhan, M. A., G. W. Chong, R. M. Reich, and **T. J. Stohlgren**. 2000. Landscape-scale assessment of plant diversity under mountain terrain: Integration of Remotely Sensed Data, GIS, and Spatial Statistics. In: ASPRS Annual Convention & Exposition, ASPRS Technical Papers, May 22-26, 2000, Washington, DC.

Nydick, K., B. Moraska, **J. Baron**, B. Johnson. 2000. Nutrient limitation experiments in subalpine lakes of the Loch Vale Watershed, Rocky Mountain National Park. North American Benthological Society (NABS) Annual Meeting, May 28-June 1, Keystone, CO.

Kalkhan, M.A., G.W. Chong, R.M. Reich, and **T.J. Stohlgren**. 2000. Landscape-scale assessment of plant diversity: Integration of Remotely Sensed Data, GIS, and Spatial Statistics. In: 2000 Shortgrass Steppe Symposium, January 12, 2000, Colorado State University, Fort Collins, CO, USA.

Kalkhan, M.A., **T.J. Stohlgren**, G.W. Chong, L.D. Schell and R.M. Reich. 2000. Landscape-scale assessment of plant diversity: Integration of Remotely Sensed Data, GIS, and Spatial Statistics. In: Eight Biennial Remote Sensing Application Conference (RS 2000), April 10-14, 2000, Albuquerque, New Mexico.

Barnett, D, M. Lee, M. Kaye, J. Bossenbroek, and **T.J. Stohlgren**. Aspen persistence in the southern greater Yellowstone ecosystem and Rocky Mountain National Park. Symposium on Sustaining Aspen in Western Landscapes, Grand Junction, CO, June 13-15, 2000.

Kaye, M.W., K. Suzuki, **D. Binkley**, **T.J. Stohlgren**. Landscape-scale dynamics of aspen in Rocky Mountain National Park, Colorado. Symposium on Sustaining Aspen in Western Landscapes, Grand Junction, CO, June 13-15, 2000.

Chong, G., **T.J. Stohlgren**, S. Simonson. Biodiversity: Aspen has the lead, but will non-native species take over? Symposium on Sustaining Aspen in Western Landscapes, Grand Junction, CO, June 13-15, 2000.

Barnett, D.T, M. Lee, M. Kaye, J. Bossenbroek, **T.J. Stohlgren**. Aspen persistence in the southern greater Yellowstone ecosystem and Rocky Mountain National Park. Poster Presentation. Ecological Society of America Annual Meeting, August 6-10, 2000.

Stohlgren, T.J., E. Keeley, and D.M. Graber. Exotic species and biodiversity in mountain forests. Invited Speaker for a special symposium at Society of Ecological America Annual Meeting, August 6-10, 2000. (PRESENTED)

Chong, G., **T.J. Stohlgren**, and S. Simonson. Biodiversity: Aspen has the lead, but will non-native species take over? Ecological Society of America Annual Meeting, August 6-10, 2000.

Simonson, S., G.W. Chong, **T.J. Stohlgren**. Exotic plant species and native pollinators: Implications for native biodiversity. Ecological Society of America Annual Meeting 2000 August 6-10, 2000.

Kalkhan, M.A, **T.J. Stohlgren**, G.W. Chong. Landscape-scale assessment of plant diversity: Integration of spatial information and spatial statistics. Ecological Society of America Annual Meeting 2000 August 6-10, 2000.

Stohlgren, T.J. Invasive species threats to National Parks. National Park Service's Discovery 2000 Conference in St. Louis, MO (Sept. 11-14, 2000). (PRESENTED)

T.T. Veblen. 2000. Climatic influences on fire history in the Colorado Front Range. Paper presented to the National Climate Assessment Workshop, NCAR, Boulder, September 2000.

T.T. Veblen, J. Sibold and R. Sherriff. 2000. Fire history of Rocky Mountain National Park. A half-day workshop presented to the scientific and management staff of RMNP, Estes Park, Oct. 16, 2000.

T.T. Veblen and T. Kitzberger. 1999. A comparison of fire ecology between the Colorado Front Range and northern Patagonia. International Bot. Congress, St. Louis, USA.

Donnegan, J. and **T. Veblen**. 1999. Fire history and its ecological consequences in Boulder County. Boulder County Nature Association, March, Boulder, USA.

T.T. Veblen. 1999. Fire regimes and their ecological consequences in the Colorado Front Range. City and County of Boulder Wildland Fire Symposium, May, Boulder, USA.

Kalkhan, M. A., G. G. Chong, R. M. Reich, and **T. J. Stohlgren**. 1999. Landscape-scale assessment: Integration of Remotely Sensed Data, GIS, and Spatial Statistics. In: GIS Day, November 17, 1999, Colorado State University, Fort Collins, CO, USA.

Stohlgren, T.J. and G. Chong. Invasive plant species monitoring and predictive modeling at the Yellowstone National Park regional conference on managing invasive species (Oct. 11-13, 1999). The talks prompted stakeholders to seek or help in preparing study proposals in Yellowstone, Grand Teton, and Rocky Mountain National Parks. (PRESENTED).

Stohlgren, T.J., and research team. Diversity and stability: Exotic plants are spoiling a perfectly good paradigm. Ecological Society of America Meetings (Aug. 6-12, 1999, Spokane, Washington).

Baron, J.S., J.R. Gosz, J.A. Estes, **T.J. Stohlgren**, and R. Herrmann. Long-term ecological research and monitoring in support of broad-scale management needs for the Department of the Interior. Ecological Society of America Meetings (Aug. 6-12, 1999, Spokane, Washington).

Chaney, N.A., W.H. Walker, **T.J. Stohlgren**, and **J.S. Baron**. Long-term monitoring in National Parks: A step towards a network of Index Sites on DOI Lands. Ecological Society of America Meetings (Aug. 6-12, 1999, Spokane, Washington).

Kaye, M.W., **T.J. Stohlgren**, and **D. Binkley**. Spatial heterogeneity of quaking aspen within Rocky Mountain National Park, Colorado. Ecological Society of America Meetings (Aug. 6-12, 1999, Spokane, Washington).

Kalkhan, M.A., **T.J. Stohlgren**, G.W. Chong, and R.M. Reich. Investigation of the spatial relationship between plant species richness and physical environment using remotely sensed data, GIS, and spatial statistics. Ecological Society of America Meetings (Aug. 6-12, 1999, Spokane, Washington).

Peer-Reviewed Publications

Baker, W.L. 2002. Indians and fire in the Rocky Mountains: The wilderness hypothesis renewed. In: Vale, T.R., editor. Fire, native peoples, and the natural landscape. Washington, D.C.: Island Press. p 41-76.

Baker, W.L. 2003. Fires and climate in forested landscapes of the U.S. Rocky Mountains. In: Veblen, T.T., W.L. Baker, G. Montenegro, and T.W. Swetnam, editors. Fire and climatic change in temperate ecosystems of the western Americas. New York: Springer-Verlag. p 120-157.

Baker, W.L., and D. Ehle. 2001. Uncertainty in surface-fire history: the case of ponderosa pine forests in the western United States. Canadian Journal of Forest Research 31:1205-1226.

Baker, W.L., P.H. Flaherty, J.D. Lindemann, T.T. Veblen, K.S. Eisenhart, and D. Kulakowski. 2002. Effect of vegetation on the impact of a severe blowdown in the Southern Rocky Mountains, USA. Forest Ecology and Management 168:63-75.

Baker, W.L., and K.F. Kipfmueller. 2001. Spatial ecology of pre-Euro-American fires in a Southern Rocky Mountain subalpine forest landscape. Professional Geographer 53:248-262.

Balk, B., and K. Elder. 2000. Combining binary decision tree and geostatistical methods to estimate snow distribution in a mountain watershed. Water Resources Research 36:13-26.

Barnett, D., and T.J. Stohlgren. 2003. A nested intensity sampling design for plant diversity. Biodiversity and Conservation 12:225-278.

Baron, J.S. 2001. Lessons learned from long-term ecosystem research and monitoring in alpine and subalpine basins of the Colorado Rocky Mountains, USA. Ekologia-Bratislava 20:25-30.

Baron, J.S., editor. 2002. Rocky Mountain Futures: an ecological perspective. Covelo, CA: Island Press.

Baron, J.S., and N. Caine. 2000. Temporal coherence of two alpine lake basins of the Colorado Front Range, USA. Freshwater Biology 43:463-476.

Baron, J.S., S. Del Grosso, D.S. Ojima, D.M. Theobald, and W.J. Parton. 2004a. Nitrogen Emissions Along the Colorado Front Range: Response to Population

Growth, Land and Water Use Change, and Agriculture. In: DeFries, R., and G.P. Asner, editors. Ecosystem Interactions with Land Use Change. AGU Press: In Press.

Baron, J.S., M.D. Hartman, L.E. Band, and R.B. Lammers. 2000a. Sensitivity of a high-elevation Rocky Mountain watershed to altered climate and CO_2. Water Resources Research 36:89-99.

Baron, J.S., R. Monson, J. Blais, and D.W. Schindler. 2004b. Atmospheric deposition of nutrients and pollutants, Millennium Assessment. Atmospheric Chemistry in Mountain Systems. sub sub chapter 3.2.2: In Press.

Baron, J.S., K.R. Nydick, H.M. Rueth, B.M. Lafrancois, and A.P. Wolfe. 2004c. High elevation ecosystem responses to atmospheric deposition of nitrogen in the Colorado Rocky Mountains, USA. In: Huber, U.M., H.K.M. Bugmann, and M.A. Reasoner, editors. Global Change and Mountain Regions: A State of Knowledge Overview. Dordrecht, The Netherlands: Kluwer Academic Publishers. p In Press.

Baron, J.S., H.M. Rueth, A.M. Wolfe, K.R. Nydick, E.J. Allstott, J.T. Minear, and B. Moraska. 2000b. Ecosystem responses to nitrogen deposition in the Colorado Front Range. Ecosystems 3:352-368.

Baron, J.S., and M.W. Williams. 2000. Recent Loch Vale watershed research - Preface. Water Resources Research 36:11-12.

Bebi, P., D. Kulakowski, and T.T. Veblen. 2004. Interactions between fire and spruce beetles in a subalpine Rocky Mountain forest landscape. Ecology *In press*.

Binkley, D. 1999. Disturbance in temperate forests. In: Walker, L., editor. Ecosystems of Disturbed Ground. Amsterdam: Elsevier Science. p 453-466.

Binkley, D. 2004. A hypothesis about the interaction of tree dominance and stand production through stand development. Forest Ecology and Management 190:265-271.

Binkley, D., U. Olsson, R. Rochelle, T.J. Stohlgren, and N. Nikolov. 2003a. Structure, production, and resource use in old-growth spruce/fir forests in the central Rocky Mountains, USA. Forest Ecology and Management 172:271-279.

Binkley, D., F.J. Singer, M. Kaye, and R. Rochelle. 2003b. Influence of elk grazing on soil properties in Rocky Mountain National Park. Forest Ecology and Management 185:239-247.

Buechling, A., and W.L. Baker. 2004. History of subalpine forest fires in the northern part of Rocky Mountain National Park, Colorado. Canadian Journal of Forest Research *In preparation*.

Burns, D.A. 2003. The effects of atmospheric nitrogen deposition in the Rocky Mountains of Colorado and southern Wyoming, USA--a critical review. Environmental Pollution 127:257-269.

Campbell, D.H., J.S. Baron, K. Tonnessen, P. Brooks, and P. Schuster. 2000. Controls on nitrogen flux in alpine-subalpine watersheds. Water Resources Research 36:37-48.

Campbell, D.H., C. Kendall, C.C.Y. Chang, S.R. Silva, and K.A. Tonnessen. 2002. Pathways for nitrate release from an alpine watershed: Determination using *15N and *18O. Water Resources Research 38:10.1029/2001WR000294.

Chase, T.N., R.A. Pielke, T.G.F. Kittel, J.S. Baron, and T.J. Stohlgren. 1999. Potential impacts on Colorado Rocky Mountain weather due to land use changes on the adjacent Great Plains. Journal of Geophysical Research-Atmospheres 104(D14):16673-16690.

Chase, T.N., R.A. Pielke Sr., T.G.F. Kittel, R.R. Nemani, and S.W. Running. 2000. Simulated impacts of historical land cover changes on global climate in northern winter. Climate Dynamics 16:93-105.

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Algal and zooplankton species lists are available in a video library on the Loch Vale website. Vegetation lists are also available, as well as long-term stream discharge, water quality, and climatic data (http://www.nrel.colostate.edu/projects/lvws/). These species lists are the first comprehensive lists of aquatic algae and invertebrates within Rocky Mountain National Park.

GEOSPATIAL REFERENCE TO THE STUDY AREA

Rocky Mountain National Park
The bounding box of the park (all in Latitude/Longitude decimal degrees):
West: -105.911926
East: -105.493031
North: 40.553807
South: 40.158081

Centroid (approximate): -105.414143 W, 40.201766 N

WEB PAGE REVIEW

Tom Stohlgren, Principal Investigator
Main Project Page: http://www.nrel.colostate.edu/projects/stohlgren/index.html
National Institute of Invasive Species Science home page:
http://kiowa.colostate.edu/cwis438/niiss/index.html

William L. Baker, Principal Investigator
Main Project Page: http://www.uwyo.edu/geog/people/wbaker.html

Jill Baron, Principal Investigator
Loch Vale Watershed Research Project:
http://www.nrel.colostate.edu/projects/lvws/pages/homepage.htm
User interface for running the RHESSys model:
https://www.nrel.colostate.edu/~lkc/rhessys_dist/rhessys.cgi
Link to calibration of the RHESSys model:
https://www.nrel.colostate.edu/~lkc/rhessys_calibration/calibration.cgi

Dan Binkley, Principal Investigator
Main Project Page: http://lamar.colostate.edu/%7Ebinkley/research.htm

Timothy G.F. Kittel, Principal Investigator
Main Project Page: http://culter.colorado.edu/~kittel/

Roger A. Pielke, Sr., Principal Investigator
Main Project Page: http://blue.atmos.colostate.edu

Thomas T. Veblen, Principal Investigator
Main Project Page:
http://www.colorado.edu/geography/news_events/facilities/biolab/biolab.html