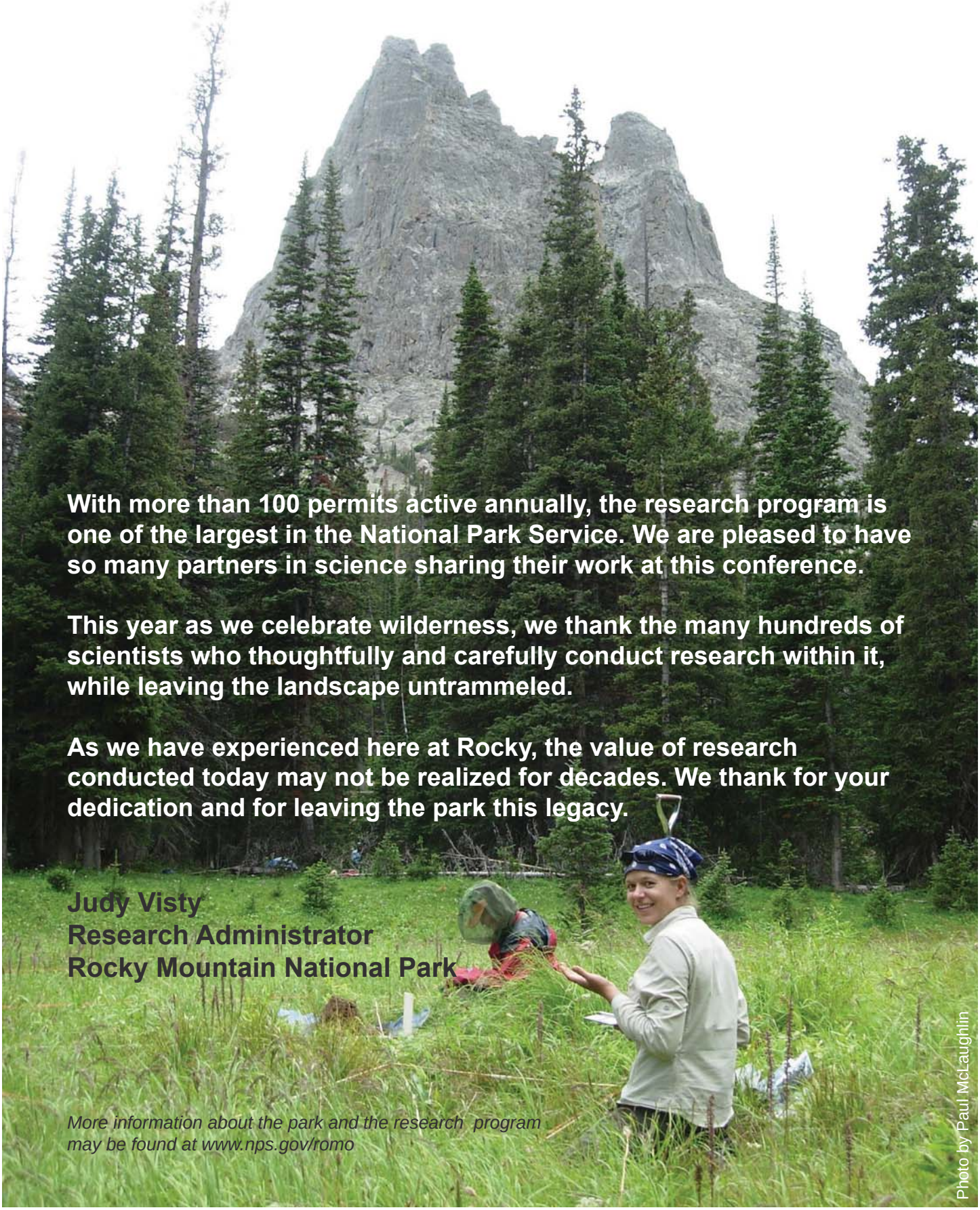
National Park Service
U.S. Department of the Interior

Continental Divide Research Learning Center

Rocky Mountain National Park Research Conference 2010

Photo by Travis Guy

Welcome to Rocky Mountain National Park's Biennial Research Conference



With more than 100 permits active annually, the research program is one of the largest in the National Park Service. We are pleased to have so many partners in science sharing their work at this conference.

This year as we celebrate wilderness, we thank the many hundreds of scientists who thoughtfully and carefully conduct research within it, while leaving the landscape untrammeled.

As we have experienced here at Rocky, the value of research conducted today may not be realized for decades. We thank for your dedication and for leaving the park this legacy.

Judy Visty
Research Administrator
Rocky Mountain National Park

More information about the park and the research program may be found at www.nps.gov/romo

Photo by Paul McLaughlin

The observations and opinions expressed in these research presentations are those of the respective researchers and presenters and should not be interpreted as representing the official views of Rocky Mountain National Park or the National Park Service.

2010 Research Conference Rocky Mountain National Park

Estes Park Municipal Building, Town Board Room ● 170 MacGregor Ave, Estes Park, Colorado 80517

Tuesday, March 30		Room A: Social Science
8:00-8:20		Coffee and welcome
8:20-8:40		Session introduction
8:40-9:00	Robert Brunswig	Cultural-Natural Landscapes and Ecological Patch Islands in Forest Canyon Pass, Rocky Mountain National Park
9:00-9:20	James Benedict	Bison Bones and Frozen Forests: The Ice-Patch Archives
9:20-9:40	Amanda Jeter	Change Over Time: Design Evolution of Timber Creek and Aspenglen Campgrounds
9:40-10:00	Sarah Eaton	Little Buckaroo Ranch: A Historic Barn in the Kawuneeche Valley
10:00-10:20		Break
10:20-10:40	Ruth Alexander	People and Nature on the Mountaintop: A Resource and Impact Study of Longs Peak in Rocky Mountain National Park
10:40-11:00	Cori Knudten	A Diminishing Shadow: Longs Peak and Auto Tourists in Postwar Rocky Mountain National Park
11:00-11:20	Ben Baldwin	Pathways to Parks – Creating Opportunities for the Next Generation of National Park Service Employees
11:20-11:40	Don Zimmerman	Enhancing the National Park Service Natural Resource Program Center Intranet Website
11:40-1:00		Lunch

2010 Research Conference Rocky Mountain National Park

Estes Park Municipal Building, Town Board Room ● 170 MacGregor Ave, Estes Park, Colorado 80517

Tuesday, March 30		Room B: Forest Health
8:00-8:20		Coffee and welcome in room A
8:20-8:40		Session introduction
8:40-9:00	Sheryl Costello	Impacts of Mountain Pine Beetle Infestation on Forested Ecosystems in the Front Range, Colorado
9:00-9:20	Jason Sibold	Disturbance and Management History Influences on Mountain Pine Beetle Outbreak Severity and Post-Outbreak Stand Development
9:20-9:40	Kellen Nelson	Mountain Pine Beetle-Related Lodgepole Pine Mortality: Multi-Scale Causes and Effects in Rocky Mountain National Park
9:40-10:00	Matthew Diskin	Forest Regeneration Trajectories in Mountain Pine Beetle-Disturbed Forests of Rocky Mountain National Park
10:00-10:20		Break
10:20-10:40	Anna Schoettle	Conserving Genetic Diversity of Limber Pine in Rocky Mountain National Park
10:40-11:00	Carissa Aoki	Serotiny in Lodgepole Pine of Rocky Mountain National Park
11:00-11:20	Peter Fleischer	Implication of Natural Disturbance Regime in the Management of the Tatra Mountains Forest
11:20-11:40	Robert Hallock	Rocky Mountain National Park Mycoblitz: An Ongoing Survey of Fungi in the Park
11:40-1:00		Lunch

2010 Research Conference Rocky Mountain National Park

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Tuesday, March 30 — Room A: Water and Air

1:00-1:20	Kathy Tonnessen	Ten Years in Ten Minutes, a Short History of the Rocky Mountains Cooperative Ecosystem Studies Unit in Cooperation with Rocky Mountain National Park
1:20-1:40	Aaron Roberts	Plankton and Planes: Pigment Control in Alpine Copepods
1:40-2:00	James McCutchan	The Rocky Mountain National Park WaterBlitz: Two Mid-Summer Snapshots of Water Quality
2:00-2:20		Break
2:20-2:40	Kristin Bunte	Sampling Pools Fines: Comparison of the Percent <2 and <6 mm from Different Grid Sampling Schemes with Pebble Counts and Volumetric Samples
2:40-3:00	Christian Carrico	Annual Cycle in Atmospheric Nitrogen Species at Rocky Mountain National Park
3:00-3:20	Bill Bowman	Effects of Simulated Nitrogen Deposition on an Alpine Ecosystem in Rocky Mountain National Park
3:20-3:40	John Ray	Ozone Health Warnings and the Spatial Distribution of Ozone in the Park

Wednesday, March 31 (11:20-2:00) Room A: Poster Session

Jill Baron	Long-Term Atmospheric Deposition and Water Quality Patterns in Loch Vale Watershed
Benjamin D. Barst	Role of Carotenoids in Ameliorating PAH-Photoinduced Toxicity
Peter Fleischer	Classification of Nature Conservation Values as a Criterion for Zoning of the Tatra National Park, Slovakia
W.R. Jacobi	Firewood as a Potential Pathway for Native or Exotic Forest Pest Species in the Southern Rocky Mountains
Jason Janke	Temperature Signature Indicators of Permafrost along Trail Ridge Road
Kristen M. Kaczynski	Willow Decline in Rocky Mountain National Park: Examining the Interactions of Drought, Ungulate Browsing, Sapsuckers, and Fungus
Stephanie Kampf	Snowmelt and Soil Moisture Distributions on Two Subalpine Hillslope Transects
Natalie Kramer	Characterizing the Valley Fill in Beaver Meadows, Rocky Mountain National Park
Kellen N. Nelson	Aspen Sucker Density and Growth Following Mountain Pine Beetle-Related Mortality in Rocky Mountain National Park
Brooke B. Osborne	A Survey of Alpine Microbial Community Response to Climate Change and Atmospheric Nitrogen Deposition
Covey Potter	Designing a Restoration Protocol for a Degraded Wetland Complex at the Headwaters of the Colorado River in Rocky Mountain National Park
Jenny Powers	Utility of Rectal Biopsy for Preclinical Diagnosis of Chronic Wasting Disease in Free-Ranging Rocky Mountain Elk
Eric Richer	Proposal for Wind Generators at the Loch Vale National Atmospheric Depositional Program Site and Andrews Creek Weather Station in Rocky Mountain National Park
Tobias Riede	Habitat Acoustics of Rocky Mountain Elk in Colorado and European Red Deer in Denmark
Brian Sanford	Implications of Hydrothermal Alteration for Landscape Stability and Environmental Geochemistry
Richard W. Scully	Inventory of *Potentilla rupincola* in Rocky Mountain National Park
Byron Straw	Assessment of Latest Glacial and Postglacial Deposits in Lake of the Clouds Cirque, Never Summer Mountains, Colorado
Nate Williamson	Impacts of Mountain Pine Beetle on Lodgepole Pine Fire Behavior in Rocky Mountain National Park

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Wednesday, March 31		Room A: Wildlife
8:00-8:20		Coffee and welcome
8:20-8:40		Session introduction
8:40-9:00	Richard Bray	Rocky Mountain Butterfly Project: The Value of Long-Term Monitoring
9:00-9:20	Kristen Meyer	Assessment of the Breeding Bird Monitoring Program at Rocky Mountain National Park
9:20-9:40	Sean Maher	Does Landscape Matter to Disease Prevalence and Occurrence?
9:40-10:00	Fred & Tena Engelman	Rocky Mountain National Park Hummingbird Survey
10:00-10:20		Break
10:20-10:40	Sara J. Oyler-McCance	Investigation into Family Relationships Among Broad-tailed Hummingbirds Using Molecular Genetic Techniques
10:40-11:00	Kate Schoenecker	Developing a More Accurate Population Survey Method for Elk in Rocky Mountain National Park
11:00-11:20	Mary Kay Watry	Developing a Non-Invasive Technique to Estimate Population Size of Bighorn Sheep in Rocky Mountain National Park Using Fecal-DNA
11:20-2:00		**Poster session in room A**

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Wednesday, March 31		Room B: Vegetation
8:00-8:20		Coffee and welcome in room A
8:20-8:40		Session introduction
8:40-9:00	Rose Banks	Invasion and Expansion of Cheatgrass (*Bromus tectorum*) in Rocky Mountain National Park
9:00-9:20	Rich Hansen	The Canada Thistle Rust Mite on Native *Cirsium* Thistles in Colorado and Wyoming
9:20-9:40	Sara Rathburn	Quantifying Fluvial Processes along Lulu Creek and the Colorado River: Planning for River Restoration in Rocky Mountain National Park
9:40-10:00	Zan Rubin	Innovative Methods to Investigate Historic Processes and Provide Context for the Restoration of Lulu City Wetland, Rocky Mountain National Park
10:00-10:20		Break
10:20-10:40	E. William Schweiger	The Vitals of Wetland: Bioassessment of Park-Scale Wetland Ecological Integrity in Rocky Mountain National Park
10:40-11:00	Isabel Ashton	Alpine Monitoring in Rocky Mountain National Park: Trends in Plant Diversity, Soil Temperature, and Soil Chemistry Across Four Alpine Peaks
11:00-11:20		Break
11:20-2:00		**Poster session in room A**

Wednesday, March 31 — Room A: Wildlife, cont.

2:00-2:20	Tobias Riede	Anatomy and Physiology of Elk Bugling
2:20-2:40	Liesl Peterson Erb	Climatic Drivers of Pika Persistence in the Southern Rocky Mountains
2:40-3:00	Rick Scherer	Status and Spatial Distribution of Amphibians in the Kawuneeche Valley
3:00-3:20	Rick Scherer	Status of Beaver in Rocky Mountain National Park
3:20-3:40	Ted Sedell	Predicting the Responses of Native Trout to Post-Wildfire Debris Flows in Headwater Streams

Wednesday, March 31 — Room B: Transportation

2:00-2:20	Peter Newman	Research to Support Implementation of Integrated Transportation Planning and User Capacity Decisions in Rocky Mountain National Park
2:20-2:40	Robert Chamberlin	Linking Transportation with Resource and Experiential Conditions at Rocky Mountain National Park
2:40-3:00	David Pettebone	Exploring Visitor Preferences for Transportation Options in Rocky Mountain National Park
3:00-3:20	Ashley D'Antonio	An Assessment of Visitor Perceptions of Recreation Resource Impacts in the Bear Lake Road Corridor of Rocky Mountain National Park
3:20-3:40	Chris Monz	Quantifying the Natural Resource Consequences of Day Use in Rocky Mountain National Park
3:40-4:00	Ken Kaliski	Modeling and Mapping Transportation-Related Noise Impacts in Protected Natural Areas

Ruth M. Alexander
Colorado State University
Ruth.Alexander@ColoState.edu

People and Nature on the Mountaintop: A Resource and Impact Study of Longs Peak in Rocky Mountain National Park

This study examines Longs Peak from the 1920s to the present, tracing the values and practices of individuals who climbed the peak, their impact on its natural resources, and rangers' efforts both to facilitate climbing and protect the peak from harm. Initially, park officials gave little thought to the management of Longs Peak. By the 1920s, the dangers of climbing on the peak forced park officials to establish management priorities for Longs. Since that time, Rocky Mountain National Park has relied on a system of limited management that has involved displacing a portion of the park's responsibility onto climbers. With rangers acting as a fulcrum, the park has tried to achieve a rough balance between natural and human forces, hoping that the harshness of the conditions on Longs would help to protect it from overuse and degradation and that climbers but lightly regulated would use their freedom responsibly. This story must be set against a backdrop of resource limitation and growing levels of visitation to frontcountry areas of the park. Given the park's funding constraints and rangers' frontcountry priorities, park officials have re-evaluated and modified management practices on Longs Peak only in response to specific events and pressures. These include the death of the well-known climber Agnes Vaille on the peak in 1925; the clamor of technical climbers to "open" the Diamond in the 1950s and 1960s; the passage of the Wilderness Act in 1964; and evidence of serious danger, crowding and resource damage on Longs' non-technical and technical routes by the late 1960s and 1970s. In recent decades, the popularity of Longs Peak has made educating visitors about "leave no trace" principles increasingly important. The park has also had to accept some fluidity in definitions of "wilderness protection" and "wilderness experience."

Longs Peak, climbing, natural resource management, wilderness, "leave no trace" ethics, history

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Carissa F. Aoki
Colorado State University
caoki@warnercnr.colostate.edu

William H. Romme
Colorado State University

Monique E. Rocca
Colorado State University

Jason S. Sibold
Colorado State University

Matthew Diskin
Colorado State University

Kellen N. Nelson
Colorado State University

Serotiny in Lodgepole Pine of Rocky Mountain National Park

Regeneration in Rocky Mountain lodgepole pine (*Pinus contorta var. latifolia*) is characterized by reproduction via two kinds of canopy seed bank: serotinous cones, which open and release their seeds only under heat from fire; and non-serotinous cones, which open and release their seeds with cone maturity. Stands with a high proportion of serotinous cones typically regenerate strongly following stand-replacing fire, whereas post-fire seedling densities often are lower in stands having mostly non-serotinous cones. The proportion of trees containing serotinous versus non-serotinous cones varies widely across individual stands, reflecting historical fire conditions, as well as offering a preview of future regeneration scenarios. Our study used data from randomly-located plots across the park to quantify the distribution of serotiny on the landscape and to try to understand the key variables controlling serotiny. We found that serotiny varied from 0-97% per stand, with an average across the landscape of 56%. Plots on the west and east side of the park averaged 64% and 40% serotiny respectively, reflecting the distinctive fire histories and elevational gradients on each side of the Continental Divide. Unlike previous work in other regions, which found a strong correlation between serotiny and elevation, our data did not correlate strongly with any single variable. We used multiple logistic regression to further explore the relationship between serotiny and the range of abiotic variables that can contribute to the occurrence of serotiny. Understanding serotiny patterns will help us gain insight into the effects of historical fire regimes on current vegetation, as well as the potential resilience of the lodgepole pine landscape to stand-replacing fire.

lodgepole pine, serotiny, regeneration

Isabel Ashton
National Park Service Rocky Mountain Inventory and Monitoring Network
isabel_ashton@nps.gov

Alpine Monitoring in Rocky Mountain National Park: Trends in Plant Diversity, Soil Temperature, and Soil Chemistry Across Four Alpine Peaks

The National Park Service has played a large role in the protection and preservation of high elevation mountain ecosystems due to their natural splendor, unique assemblages of flora and fauna, and their critical function as a source of water for much of the United States. Despite protection, alpine systems are increasingly threatened by warming temperatures, altered

precipitation regimes, and increases in air pollution. It is assumed that an upward and northward migration of plants, induced by recent climate warming, is an already ongoing process, but such changes in vegetation composition are not well understood or documented due to a paucity of long-term monitoring. The Rocky Mountain Inventory and Monitoring Network began monitoring alpine vegetation, soil chemistry, and soil temperature at four peaks in Rocky Mountain National Park during the summers of 2008-2009. We adopted a protocol from the Global Observation Research Initiative in Alpine Environments (GLORIA) that uses an array of plots to measure vegetation and soil temperatures across sets of four neighboring peaks. Sentinel sites were established at four peaks, Jackstraw Mountain and three unnamed peaks on the ridge to Mount Ida ranging in elevation from 3520 to 3862 m. There were 106 species of vascular plants identified from the four sites with similar number of species on each peak, where most had about 60 vascular plant species. In general, we found more species of lichens in a 1 m^2 plot than vascular plants, and lichen species number was consistent across summits and aspects, with plots averaging 27 species. Soil temperatures remained below freezing for most of the period between October and May, but there was some variation across peaks and aspects. Continued monitoring of the vegetation and temperature at these sites will allow us to determine whether climate is affecting the biodiversity in the alpine.

alpine, vegetation, soil temperature, lichens, climate change

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Ben Baldwin
Rocky Mountain National Park
ben_baldwin@nps.gov

Pathways to Parks – Creating Opportunities for the Next Generation of National Park Service Employees

Pathways to Parks is an initiative of the Research Learning Center. Pathways is a three staged approach: information, involvement, and internships, to provide people with increased opportunities to get personally connected to the National Park Service. This initiative provides a framework that helps organize, leverage, and increases the visibility and availability of existing programs and projects. These projects provide multiple entry points that vary in level of involvement and commitment. They include: learning opportunities, volunteering, citizen science projects, service learning, shadowing and internship programs. The program has a strong focus on mentoring and professional development aimed to help volunteers and employees build networks and develop competencies to advance their career. Examples of current efforts include the Beaver Blitz, a volunteer citizen science project assessing beaver presence in the park, and the Eagle Rock Internship Program, a partnership with a local high school that provides internships to volunteer and work as STEP employees in the park.

internship, citizen science, service learning, volunteer, mentoring

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Rose Banks
University of Wyoming
ebanks@uwyo.edu

William L. Baker
University of Wyoming

Invasion and Expansion of Cheatgrass (*Bromus tectorum*) in Rocky Mountain National Park

Cheatgrass (*Bromus tectorum*), a winter-annual grass native to Eurasia, is one of the most widely distributed and damaging invasive annual grasses in North America. We studied the spatial distribution of cheatgrass in Rocky Mountain National Park, examining possible dispersal and disturbance mechanisms and inherently susceptible environmental characteristics that may facilitate the spread of cheatgrass in the park. We distinguished facilitating factors related to land uses and natural processes, and assessed potential risk of invasion into the park's imperiled vegetation. We mapped (with GPS) randomly selected reaches of roads, trails, and in natural vegetation, and for each patch, recorded (1) patch size, (2) percent cover of cheatgrass, (3) characteristics of microenvironments, and (4) amount of cheatgrass within microenvironments. Using GIS, we calculated three measures of abundance of cheatgrass in reaches: (1) mean percent cover, (2) density, and (3) mean size, and used MANOVA to assess the effect of facilitating factors. We found that cheatgrass is concentrated on the east side of the park, particularly on south-facing slopes and in areas of disturbance. In addition, while human-caused disturbances are primary sources of cheatgrass invasion, it is spreading into areas of natural vegetation due to other dispersal agents (e.g., animals) and naturally susceptible vegetation and microenvironments. Based on our results, we suggest possible ways to frame strategic direction for management and

control, such as expanding current treatment, focusing on areas where there is most potential to prevent further invasion, and doing pre- and post- disturbance treatment where disturbances are planned.

cheatgrass, disturbance, invasion, spatial distribution, rare vegetation, exotic plants

Jill Baron
U.S. Geological Survey
jill@nrel.colostate.edu

Eric Richer
Colorado State University

Long-Term Atmospheric Deposition and Water Quality Patterns in Loch Vale Watershed

Wet atmospheric nitrogen deposition, which is elevated over background values, has averaged about 3.2 kg N ha^{-1} yr^{-1} since 1998. The concentrations of nitrate and especially ammonium in wet deposition have been increasing since 1984 (with the differences in deposition and concentration explained by variable precipitation amounts). Water quality values since 2000 display patterns that appear to be unrelated to atmospheric deposition, and are more consistent with warm summer temperatures and melting glaciers, rock glaciers, and permafrost at the highest elevations. Our poster presents an update of deposition and water quality patterns in Loch Vale through 2009, showing a continued increase in the concentrations of weathering products (calcium, magnesium, sulfate), but a decline in nitrate concentrations at The Loch outlet. Summer and fall Sky Pond inlet solute concentrations remain high. We will interpret these data in light of our understanding of deposition and climatic trends.

Loch Vale watershed, atmospheric deposition, water chemistry, The Loch, Sky Pond, nitrate

Benjamin D. Barst (presenter)
University of North Texas
benbarst@hotmail.com

Matthew J. Kovach
University of North Texas

Karista E. Hudelson
University of North Texas

James D. Smith
University of North Texas

Aaron P. Roberts
University of North Texas
Aaron.Roberts@unt.edu

Role of Carotenoids in Ameliorating PAH-Photoinduced Toxicity

Alpine zooplankton are exposed to a variety of stressors in their natural environment including ultraviolet radiation and cold temperatures. Elevated levels of carotenoid compounds such as astaxanthin have been shown to help zooplankton tolerate high levels of ultraviolet radiation. However, little work has focused on the ecotoxicological implications of carotenoid compounds in alpine ecosystems and the role they may play in ameliorating anthropogenic stress. We sampled populations of alpine copepods (*Diaptomus shoshone*) from different lakes at elevations ranging from 9,500' to 12,700' in the front range of the Colorado Rocky Mountains. Carotenoid content was measured via HPLC, and challenge tests assessing tolerance to polycyclic aromatic hydrocarbon phototoxicity were carried out. Copepod populations varied in color phenotype as well as carotenoid content. Tolerance to polycyclic aromatic hydrocarbon phototoxicity was positively correlated with carotenoid content and related to color phenotype. These studies suggest that carotenoids may impart increased tolerance to anthropogenic stressors and maintaining dietary sources/transport of these compounds in alpine foodwebs is important.

copepods, carotenoids, photoxicity, alpine lakes, PAHs

James B. Benedict
Center for Mountain Archeology
no email address

Bison Bones and Frozen Forests: The Ice-Patch Archives

Front Range cirque glaciers and ice patches have been shrinking since the 1850s. Severe melting during the summers of 1977, 1981, 1987, and 2002 led to the exposure of fragile organic remains that had been frozen for thousands of years. Skulls, leg bones, horn sheaths, and molars show that bison have grazed in the alpine tundra of Rocky Mountain National Park since at least 3270 ± 15 BP. Stable-isotope measurements (δ13C) suggest that the animals were migratory, feeding on C3 grasses above timberline in summer, and on C4 grasses at lower altitude in winter. In addition to bison remains, the trunks and rooted stumps of timber-sized spruce trees have emerged from beneath melting ice patches in the Mummy Range. In order for trees to have become established in such unlikely locations, forest vegetation must have blanketed the tundra upland to the west, intercepting windblown snow. Coring of humus-rich soil horizons on the northwest slope of Rowe Mountain, upwind from the ice patches, confirmed the former presence of high-altitude forest. Sclerotia (the resting stages of mycorrhizal fungi) with diameters typical of spruce-fir forest vegetation occurred as much as 120 m above modern tree limit. They were associated with wood-

charcoal particles too large to have been transported by wind. The results of radiocarbon dating are not yet available, but are expected to be in the range of 5800–5300 BP. Dates for the outermost growth rings of ice-patch spruce trees show that timberline had retreated to its present altitude by 3860 ± 15 BP. Retreat may have been influenced as much by the dynamics of wind-drifted snow as by regional climatic change.

Bison bison, Picea engelmannii, tree limit, windblown snow, ice patches, sclerotia, climatic change

William D. Bowman
University of Colorado, Boulder
william.bowman@colorado.edu

Effects of Simulated Nitrogen Deposition on an Alpine Ecosystem in Rocky Mountain National Park

Increases in the deposition of reactive nitrogen (N) into sensitive ecosystems of Rocky Mountain National Park has raised concern about the potential for loss of diversity and ecosystem services. An experiment to estimate the potential effects of N deposition on alpine plants and soil was initiated in 2007 in an alpine dry meadow above Chapin Pass, which has an ambient N deposition rate of 4 kg N/ha/yr. Experimental N additions (0, 5, 10, and 30 Kg N per ha) were added to five replicate 1 m x 1.5 m plots. Response variables included plant species composition and abundance (annual), inorganic N flux (resin bags and microlysimeters), extractable soil cations, soil pH, and aboveground biomass (after three years of treatment). There were no changes in plant species richness with treatment or time, nor did the Shannon-Wiener diversity index, which incorporates both species richness and evenness, change. Significant increases in the sedge *Carex rupestris* occurred in a dose dependent manner. The rate of change in *C. rupestris* cover provided an estimate of "N critical load" of 3 kg N/ha/yr for the Chapin Pass site. Total aboveground plant biomass did not change in response to the treatments, but the biomass of grasses and sedges did increase significantly with increases in N. The dominant soil cations were Ca2+ and Mg2+, which did not change with the treatments, although there was a trend towards lower concentrations at the highest N inputs. Extractable Al3+, a toxic element to many organisms, and soil pH did not change with increasing N input. The results of this experiment indicate a low N input threshold exists for ecological change in alpine dry meadows of the park, consistent with results from aquatic studies and experiments on nearby Niwot Ridge, and raise concerns about the potential for future changes in soil acidification.

nitrogen, critical load, Chapin Pass, Carex rupestris, soil acidification

Richard Bray
Rocky Mountain National Park
mtlep@earthlink.net

Jan Kilgore
Rocky Mountain National Park

Rocky Mountain Butterfly Project: The Value of Long-Term Monitoring

Long-term monitoring is of value to the National Park Service. The time span for monitoring is dependent on the species and protocols. In spring 2010, this citizen science project will enter its fourteenth season of inventorying and monitoring park butterflies. The species list has grown from 94 to 139 confirmed species. The volunteers have entered sightings and weather data into a database that now includes over 74,000 butterfly sightings. Analysis is underway. Trends in the data may reveal butterfly lifecycles on the local level, but no obvious correlation to environmental factors such as climate change have emerged. If we had stopped after five or ten years, trends in the butterfly communities would have led to the conclusion that nitrogen, elk or drought have affected the communities. With almost fifteen years of data, the natural patterns of butterflies in the high elevation environment are revealed. Even with long-term monitoring, there is indeed danger of jumping to conclusions.

butterfly, inventory and monitoring, citizen science

Robert H. Brunswig
University of Northern Colorado
rhbruns@unco.edu

James Doerner
University of Northern Colorado

David Diggs
University of Northern Colorado

Jeffrey Connor
Rocky Mountain National Park

Leanne Benton
Rocky Mountain National Park

Karin Edwards
Rocky Mountain National Park

Cultural-Natural Landscapes and Ecological Patch Islands in Forest Canyon Pass, Rocky Mountain National Park

In the summer of 2008, University of Northern Colorado and Rocky Mountain National Park scientists conducted interdisciplinary studies of the park's Forest Canyon pass. That project is the first of a planned, longer-term research program including archeological survey, paleoclimatic/paleoenvironmental studies, modern botanical and faunal surveys, and initial Geographic Information System (GIS) modeling of prehistoric through historic Native American occupations. Forest Canyon pass research is driven by a cultural ecosystems theoretical approach known as Patch Island Ecology. This paper details the project's to-date results which go far in confirming its working hypothesis that Forest Canyon pass, home to the ancient Ute Trail and an unusually rich concentration of natural resources, was one of the park's most heavily utilized areas, with seasonal camp occupations dating between 9,500 and 150 years ago.

archeology, Ute, patch island ecology

Kristin Bunte
Colorado State University
kbunte@engr.colostate.edu

Kurt W. Swingle
Boulder, CO

John P. Potyondy
USDA Forest Service

S.R. Abt
Colorado State University

Sampling Pools Fines: Comparison of the Percent <2 and <6 mm from Different Grid Sampling Schemes with Pebble Counts and Volumetric Samples

Streambed surface fines can be assessed using grid counts or pebble counts. In a grid count the number of particles < 2 and < 6 mm underlying 50 grid intersections spaced 2-inch apart is counted and expressed as percentage. The Forest Service PIBO method places grids at 25, 50, and 75% of the wetted width 1 m upstream of a pool tail crest and samples over ten pools. This study, conducted at the North St. Vrain Creek in Wild Basin, compared the percent fines obtained from different grid placements within the pool tail crest area, varying areal coverage and location. Fines tended to be more plentiful towards the channel margins, thus sampling schemes that extend further towards the margins yielded more fines than those confined to the central half or third of the wetted width. The longitudinal variability over a three feet distance within the pool tail crest area was not significant, thus errors in identifying the target sampling location 1 m upstream from the riffle crest had no major effect. Operator variability can be significant though: the two study operators counted similar numbers of fines < 6 mm, but differed in the number of fines < 2 mm.

Comparison of the percent fines < 2 and < 6 mm from the PIBO grid counts with pebble counts conducted in the central half of pool tail crest area within pebble counts showed a similar trend for the two methods (i.e., pools with high grid count fines had also high pebble count fines). However, pebble counts generally had fewer fines than grid counts, owing to the better identification of fines when observing the bed through a plexiglass viewer compared to identifying fines by touch in a pebble count in flows a foot deep. Pebble counts covering the wetted and the bankfull width indicated considerably more fines than obtained from grids counts, due to a concentration of fines on and near bars and in backwaters. Volumetric samples of the armor layer indicated about double the percentage of fines as grid counts, while subarmor and subsurface sediment had five to 10 times more fines. Thus, results from grid counts, pebble counts, and volumetric samples are not interchangeable.

pools fines, grid sampling schemes, pebble counts, volumetric samples

Christian M. Carrico
Colorado State University
carrico@lamar.colostate.edu

Jeffrey L. Collett
Colorado State University

Sonia M. Kreidenweis
Colorado State University

Ezra Levin
Colorado State University

Misha Schurman
Colorado State University

Derek Day
Colorado State University

Katherine Beem
Colorado State University

John Ray
National Park Service

Bret Schichtel
National Park Service

William Malm
National Park Service

Annual Cycle in Atmospheric Nitrogen Species at Rocky Mountain National Park

Atmospheric deposition of nitrogen compounds to alpine ecosystems is a growing concern in the Rocky Mountains. Rocky Mountain National Park, adjacent to both urban and agricultural centers in Colorado, is particularly sensitive due to its pristine, nitrogen limited ecosystems. As part of the Rocky Mountain Atmospheric Nitrogen Study (RoMANS), we investigated the annual cycle of atmospheric nitrogen speciation in the park. From November 2008-2009, several high time resolution techniques were deployed at the long-term IMPROVE monitoring site. This study focuses on high time resolution measurements of gas-phase concentrations of ammonia and NOy compounds, using modified versions of commercially available instruments. Modifications include enhanced speciation on time scales of minutes to hours, potentially important because of the episodic nature of transport and deposition. At distinct times, oxidized versus reduced species predominated at the park in 2009. Reduced nitrogen, identified using two online techniques as gas phase ammonia, was the largest identified contributor to the gas phase nitrogen budget at the park. Ammonia concentrations demonstrated a distinct diurnal and seasonal profile showing peaks both midday and in the summer season. Nitrogen oxides demonstrated less seasonal and diurnal dependence, responding more on an event basis often associated with easterly upslope flow and precipitation. Ongoing analysis of the results from RoMANS is intended to inform policy efforts aimed at minimizing adverse nitrogen deposition at Rocky Mountain National Park.

air quality, visibility, ammonia, nitrogen oxides, NOy, deposition, ecosystem impacts

Robert Chamberlin
Resource Systems Group Inc.
rchamberlin@rsginc.com

Steve Lawson
Resource Systems Group Inc., White River Junction, VT

Linking Transportation with Resource and Experiential Conditions at Rocky Mountain National Park

Rocky Mountain National Park's Bear Lake Road corridor has a high degree of visitor access. In 1929 there was a 100-car parking lot constructed at the Bear Lake trailhead. In 1978 the park initiated transit service within the corridor which has since evolved into a high capacity system. In 1998 a 390-space park-and-ride lot was constructed mid-corridor to serve as a transfer point. ROMO is evaluating the linkages between this visitor delivery system and resource conditions and visitor perceptions of crowding and biophysical impacts to the trail. This paper quantifies the visitor delivery system in the corridor, inclusive of transit and private vehicle access. Alternative visitor delivery systems are investigated–including modifying bus capacity, bus headway, parking lot capacities, and traveler information systems–that affect the timing and magnitude of visitor arrivals at these key venues.

Bear Lake Road, park-and-ride, shuttle, visitor perception

Sheryl Costello
USDA Forest Service
scostello@fed.fs.us

Jenny Briggs
U.S. Geological Survey

Dan West
Colorado State University

Sky Stephens
Colorado State Forest Service

Jose Negron
USDA Forest Service

Jen Klutsch
USDA Forest Service

Impacts of Mountain Pine Beetle Infestation on Forested Ecosystems in the Front Range, Colorado

Epidemic populations of the mountain pine beetle (MPB, *Dendroctonus ponderosae)*, are spreading through Colorado's lodgepole pine forests and moving east of the Continental Divide. This native insect represents a potentially major source of disturbance to mixed conifer and ponderosa pine ecosystems in the Front Range. It is unknown whether a) MPB will fully switch hosts to ponderosa pine from its original host species, lodgepole pine; and b) if past or future forest management practices in ponderosa ecosystems may affect the resilience of trees and stands to attack. In 2009, we initiated a study to address both questions by measuring MPB activity (2003-2009) and tree/stand characteristics in a) mixed lodgepole/ponderosa forest and b) pure ponderosa stands that were previously treated by strategies such as thinning and prescribed burning, or not treated (controls). We established four study sites in the park and 11 sites elsewhere to address the first question, with three sets of monitoring transects and plots per site. Preliminary results reveal considerable among-site variation in recent MPB activity in both lodgepole and ponderosa pine: 2-58% of trees in our monitoring transects were newly attacked by MPB in fall 2009, with the higher levels of activity in both species at sites near Estes Park and further north. Additional analyses and surveys in the coming years should provide insight into the stand, tree, and site characteristics correlated with MPB activity. Study results should assist managers at the park and elsewhere to plan their response, mitigation, and education efforts in the face of this potentially significant forest disturbance process.

mountain pine beetle, host transition, lodgepole pine, ponderosa pine, thinning, prescribed burning

Ashley D'Antonio
Utah State University
ashleydantonio@gmail.com

Chris Monz
Utah State University

An Assessment of Visitor Perceptions of Recreation Resource Impacts in the Bear Lake Road Corridor of Rocky Mountain National Park

Recreation impacts and resource conditions have the potential to influence visitor experience in parks and protected areas. Of particular concern to researchers are visitor perceptions of recreation impacts and the factors that may influence these perceptions. Perceived impacts have the potential to affect the quality of visitor experiences and managers of parks and protected areas are concerned about recreation impacts that reduce visitor enjoyment and impair the resources used by visitors. An understanding of how visitors perceive environmental conditions, which recreation impacts visitors deem unacceptable, and visitor characteristics that influence individual perceptions can provide guidance for management decisions. An on-site questionnaire was administered in the Bear Lake Road corridor to examine visitor perceptions of recreation resource impacts. The study examined visitor characteristics that may influence visitor perceptions of specific resource conditions and visitor standards for resource impacts. Visual research methods were utilized to determine visitor standards for specific resource impacts. The minimally acceptable condition for both vegetation cover loss and the proliferation of visitor created trails was determined using visual research methods. Preliminary results indicate that 52% relative vegetation cover loss is the minimum acceptable condition for vegetation. For the proliferation of visitor created trails, visitors found the minimum acceptable condition to be 6% of the area impacted by visitor created trails. This approximates to two typical visitor created trails in the visitor viewscape. Additional analyses examined the influence of such characteristics as experience use history, local ecological knowledge, and knowledge of Leave No Trace practices on visitor perceptions. Further analyses also identified specific resource impacts, such as erosion, trampled vegetation, proliferation of visitor created trails, and crowding, which are being perceived by visitors and how these impacts affected the visitor experience.

recreation impacts, "Leave No Trace" ethics, visitor enjoyment, visitor perceptions, Bear Lake Road corridor

Matthew Diskin
Colorado State University
mattdiskin@gmail.com

Monique E. Rocca
Colorado State University

Kellen N. Nelson
Colorado State University

Carissa Aoki
Colorado State University

William H. Romme
Colorado State University

Forest Regeneration Trajectories in Mountain Pine Beetle-Disturbed Forests of Rocky Mountain National Park

Forests in Rocky Mountain National Park are undergoing substantial changes due to a mountain pine beetle epidemic that has caused widespread mortality of lodgepole pine trees. The future of these forests is unknown, and a great concern for the public and land managers. The objectives of this study of beetle-disturbed forests in the park are to: 1) describe the initial effects of mortality on forest structure and composition; and 2) project future forest conditions using the Forest Vegetation Simulator. We measured standard forest attributes in 75 randomly located plots during the summer of 2008 in the lodgepole pine forests of the western portion of the park. To describe variability in post-epidemic forest conditions, five lodgepole pine forest types were defined using a cluster analysis. Even with anticipated future mortality, our results indicate that surviving trees, including larger canopy trees and saplings, were plentiful in most of the post-epidemic forests. Immediately following the epidemic, subalpine fir, Engelmann spruce, and aspen were relatively more abundant than before the epidemic, but increases tended to be small or moderate. In projections of future forest conditions, pre-epidemic basal area is recovered within 60 years in most areas, although some areas remain below pre-epidemic basal area 100 years in the future. Lodgepole pine remains dominant on a large part of the landscape in the projected future forests, although projections indicate a possible transition to spruce-fir and aspen dominated forests on over half the study area. These projections offer a best guess of possible future conditions in the park, but should be used cautiously as many unpredictable forces will likely shape future forests. Forest structure and composition varied considerably among the five forest types both before and after the epidemic as well as in the projected future forests. These results suggest that active efforts to "restore" lodgepole pine forests in the park will not be necessary and that post-epidemic forest regeneration trajectories will be highly variable. This information is particularly important for the park's education efforts and we would like to make it available to park visitors.

lodgepole pine, mountain pine beetle, forest regeneration

Sarah Eaton
Rocky Mountain National Park
kountess@bellsouth.net

Little Buckaroo Ranch: A Historic Barn in the Kawuneeche Valley

Although Rocky Mountain National Park was once home to numerous summer houses and ranches, few of these structures remain. Little Buckaroo Ranch, located on the western side of the park, is one of the few survivors. The property received national attention when Betty Dick, whose lease on the property was about to expire, received permission from Congress in 2006 to continue to occupy the property until her death. After Mrs. Dick's death later that year, the park wished to determine whether the property was eligible for listing in the National Register of Historic Places.

An evaluation of the property in late-2008 found that while the entire property did not appear eligible for National Register listing at the present time, a unique barn on the property clearly met the criteria. A nomination for the barn was then prepared and presented to the Colorado National Register Review Board on May 8, 2009. The barn was listed in the National Register on July 8.

Little Buckaroo Ranch Barn is a highly uncommon Colorado barn. Built in 1942, the barn is an unusual hybrid and represents a rare melding of a type of barn found almost exclusively in southern Louisiana with the materials that are characteristic of the Rocky Mountain National Park area. The barn's small size, square shape and monitor roof reflect the influence of the barns of Louisiana, while its use of rustic materials represents an excellent local adaptation to its Colorado setting.

Little Buckaroo Ranch, Betty Dick, historic property, architecture, National Register of Historic Places

Fred Engelman
Rocky Mountain National Park
fcengelman@earthlink.net

Tena Engelman
Rocky Mountain National Park

Rocky Mountain National Park Hummingbird Survey

Analysis of seven years of field research on the park's hummingbird populations is enabling insights on species, migration routes, survivorship and longevity, reproductive success, and demographics. Researchers have captured, banded, measured and released 7,589 hummingbirds of four species. Broad-tailed hummingbirds (*Selasphorous [S.] platycercus*), the spring and summer breeding and nesting residents, comprise an average of 85% of hummingbird species observed, while rufous (*S. rufus*) and calliope (*Stellula calliope*) average 13% and 2% respectively. A single ruby-throated hummingbird (*Archilochus colubris*), the first park record and seventh state record, was banded and released in 2004.

Limited broad-tailed foreign encounter information indicates that main migration routes closely follow the Rocky Mountains and that the Continental Divide may not be a major factor in choice of routes. Banding data and capture of gravid females showed relative nesting and fledging success varied with spring and summer weather conditions and availability of nectar flowers and insects, as expected. Fledging success appeared best in 2007 with 1.5 hatch year birds per trap hour and worst in 2005 with 0.7 per trap hour.

For undetermined reasons, calliope hummingbirds appear to migrate through the park in relatively small numbers. The peak year for calliope numbers (3% of total) was in 2008, and it coincided with a mid-summer drought that reduced nectar flower availability and increased visits to banding site feeders.

Numbers of rufous hummingbirds transiting the park each summer from farther north vary considerably each year with the best year in 2003 and the smallest numbers in 2004. The annual ratio of after hatch year to hatch year rufous has varied in a similar manner. Two rufous banded in the park have been encountered in Alberta and British Columbia, Canada during their nesting season, over 1,000 miles from their banding location.

ornithology, inventory and monitoring, hummingbirds, population dynamics, rare species

Liesl Peterson Erb
University of Colorado, Boulder
liesl.peterson@colorado.edu

Robert Guralnick
University of Colorado, Boulder

Chris Ray
University of Colorado, Boulder

Climatic Drivers of Pika Persistence in the Southern Rocky Mountains

Alpine species are among those most threatened by climatic shifts due to their physiological and geographic constraints. The American pika (*Ochotona princeps*), an alpine mammal found in rocky habitats throughout much of western North America, has experienced recent population extirpations in the Great Basin of the United States. These trends have been linked to climatic drivers, and the species was recently considered for protection under the Endangered Species Act (ESA). The species was not listed under the ESA, in part because it remains unclear whether the patterns of climate-related loss observed within the Great Basin extend to other portions of the species' range. Currently, we are investigating the distribution of the American pika and the climatic processes driving these patterns within the Southern Rocky Mountain region. Following a resurvey of 69 sites historically occupied by pikas, data indicate that few populations have been extirpated within this region over the past few decades. Despite relatively few extirpations, low annual precipitation is implicated as a limiting factor for pika persistence in the Southern Rockies. Extirpations occurred only at sites that were consistently dry over the last century, and two of these four sites were in Rocky Mountain National Park. While there is no climate change signal in these results, these data provide valuable insight into the potential future effects of climate change on *O. princeps* throughout its range. They also demonstrate the importance of monitoring climate as well as pika population dynamics in Rocky Mountain National Park.

pika, Ochotona princeps, climate change, precipitation

Peter Fleischer (presenter)
Research Station and Museum of Tatra National Park, State forest of TANAP
pfleischer@lesytanap.sk

Slavomir Celer
Administration of Tatra National Park, State Nature Conservancy, Tatranska Strba
celer@sopsr.sk

Classification of Nature Conservation Values as a Criterion for zoning of the Tatra National Park, Slovakia

According to the conservation aims of the Tatra National Park naturalness and rarity of ecosystems were chosen as the main criteria for classification of nature conservation values. Naturalness of forest and subalpine vegetation was ranked as a degree of deviation from model of potential vegetation. Potential or natural (pristine) ecosystems were identified and mapped in 1950s-1980s during national inventory of forest geobiocenosis. Soil properties, ground vegetation and tree species composition were often the key criteria for categorization. This approach failed in the central part of the Tatra Mountains where forest vegetation differs significantly from the rest of the Slovakian mountains. We confirmed vertical and spatial structure of stands as a reliable indicator of naturalness on tested plots with well documented land-use history (forest archives and evidence, historical drawings and photographs, pollen analysis etc.). We used five ranks for classification of naturalness (ranging from pristine to monocultures), based on measurable signs and parameters. Spatial distribution of naturalness categories was worked out by combination of ground survey and GIS interpretation of aerial maps.

The most valuable categories (natural and mostly natural) were concentrated in the most remote parts of the Tatra Mountains. Our findings also confirmed that even-age like forest in the central part of the Tatra Mountains was caused by repeated heavy windstorms and not by past forest overuse as it was interpreted before.

Pronounced vertical and spatial diversity in natural stands should guarantee high resilience to any kind of disturbance without any human assistance; thus we designated these ecosystems into A (no management zone) of the park. On the contrary, those ecosystems that suffer from repeated windstorms and need forestry-management assistance were proposed to C (managed) zone of the park.

Tatra Mountains, nature conservation value, naturalness, forest structure, zoning, GIS

Peter Fleischer
Research Station and Museum of Tatra National Park, State forest of TANAP
pfleischer@lesytanap.sk

Implication of Natural Disturbance Regime in the Management of the Tatra Mountains Forest

Forest forms an important part of the Tatra Mountains nature. It covers 50 000 hectares (70% of the park). Dominant species are conifers (*Picea abies* is 65%, *Pinus sylvestris* 10%, *Abies alba* 8%, *Larix decidua* 8%). This forest called extrazonal central European taiga is a consequence of climatic, geographic and geomorphologic conditions of the Tatra Mountains. A natural part of local anemo-orographic system is the occurrence of downslope winds with large impact on the forest. Strong windstorms happened every 40-70 years and block forest ecosystem development towards the climax stage. The last and the largest windfall in the park's history happened in 2004 (230 km/h wind speed, 2.3 mil m 3 of fallen trees on 12 000 hectares). High risk of fires, floods and bark beetle outbreaks lead to the decision to remove fallen wood from 90% of the affected area. Despite this, the area has experienced more than 20 fires, and bark beetles attacked more than 4000 hectares of standing forest due to recent extremely warm growing seasons.

Differentiated management of windfall stimulated an international ecological research and monitoring. The objective is to understand reasons, consequences and future development of affected forest ecosystems and to propose the most suitable management for improving its ecological stability and services. Research compares data gathered from numerous permanent plots before 2004 with the current situation (e.g. climate, hydrology, soil-hydric conditions, vegetation and fauna). Preliminary results have confirmed significant changes in microclimate and soil-hydrological conditions with an evident influence on mineralization, nutrient leaching, C and N flux, vegetation and soil fauna during the first two years after the storm. The situation has improved with dynamic development of vegetation succession. Current forest rehabilitation and management tends to form more open stands with strong vertical and spatial heterogeneity to safeguard continuous ecological and environmental services in the Tatra National Park.

windfall, Norway spruce, weather extremes, bark beetle, forest services, rehabilitation

Robert M Hallock
University of Colorado Denver
rob.hallock@ucdenver.edu

Vera Evenson
Denver Botanic Gardens

Michael Kuo
Eastern Illinois University

Rocky Mountain National Park Mycoblitz: An Ongoing Survey of Fungi in the Park

The Rocky Mountain National Park mycoblitz was a survey of fungi in the park. We spent one weekend in August of 2008 during the peak of the summer mushroom season and one weekend during the tail-end of the fall mushroom season in September of 2009. In all, approximately 100 volunteers organized by the Colorado Mycological Society (CMS) spread out across the park to document, photograph, and collected fungi. Mushrooms were photographed in the field, carefully collected, and brought back to the park headquarters. Specimens were documented, dried, and kept in the Denver Botanic Gardens Herbarium of Fungi. In total, approximately 250 distinct mushroom species have been documented and categorized in the park. Approximately half of the specimens found in 2009 were not found in 2008, indicating that targeting different time frames of mycoflora was successful. In total, many specimens of most common genera in the state of Colorado have been identified in the park. For example, six species from the genus *Agaricus* were found. In addition, numerous examples of *Cortinarius*, *Russula*, and members of the *Boletaceae* were documented. Additionally, some rare mushrooms have been identified in the park. Mushrooms that are rare in Colorado include the likely-poisonous *Lepiota felina* and the mildly hallucinogenic *Pluteus brunneidiscus.* This ongoing project significantly increases the number of mushrooms that are known to grow in Rocky Mountain National Park and identifies specific habitat in the park conducive to mushroom growth.

fungi, mushrooms

Rich Hansen
U.S. Department of Agriculture
richard.w.hansen@aphis.usda.gov

The Canada Thistle Rust Mite on Native *Cirsium* Thistles in Colorado and Wyoming

The Canada thistle rust mite, *Aceria anthocoptes* (*Acari: Eriophyidae*), is a European native that feeds on thistle leaves. European studies indicated that the mite feeds only on Canada or creeping thistle, *Cirsium arvense (Asteraceae)* and perhaps a few closely-related Eurasian *Cirsium* thistles. *A. anthocoptes* has been accidentally introduced into the United States, where Canada thistle is a widespread exotic weed. Mites have been collected from Canada thistle populations in eastern, midwestern, and western states. There is a widespread, diverse native *Cirsium* flora in North America, with at least 80-90 species present in the United States. My goal was to determine if *A. anthocoptes* could utilize native *Cirsium* thistles under field conditions. To date, 11 native thistles have been sampled in Colorado and Wyoming, including four in Rocky Mountain National Park: fringed thistle (*Cirsium centaureae*), meadow thistle (*C. scariosum*), mountain thistle (*C. scopulorum*), and wavyleaf thistle (*C. undulatum*). We have collected *A. anthocoptes* from 10 of 11 native thistles sampled through 2009, including all four species sampled in the park; mites were collected annually from the four park thistles from 2006 through 2009. In general, mites are about as abundant on native thistles as they are on the presumed host, Canada thistle.

Thus, we believe that the host range of *Aceria anthocoptes* is broader than originally documented, and that most or all native *Cirsium* thistles could support mite populations. However, we have observed no foliar damage on Canada thistle or any native thistles that could be reliably attributed to *A. anthocopte*s feeding. This suggests that mite populations are typically maintained at sub-damaging levels by natural enemies, weather factors, and/or other environmental variables. Interestingly, no mites were collected from the exotic weed bull thistle, *Cirsium vulgare*, at the park and other Colorado sites, confirming European observations that it is not an *A. anthocoptes* host.

Canada thistle, plant-feeding mites, native plants, Cirsium spp.

W.R. Jacobi
Colorado State University
william.jacobi@colostate.edu

C. M. Cleaver
Colorado State University

J. A. Hardin
Colorado State University

B.A. Goodrich
Colorado State University

Firewood as a Potential Pathway for Native or Exotic Forest Pest Species in the Southern Rocky Mountains

Firewood can harbor harmful insects and pathogens and facilitate the transport of these organisms within a state or across state or national borders. There are currently a considerable number of invasive native or exotic species we hope to prevent from moving into new areas of the United States. In 2008, approximately 4.3 million people camped in national parks in the southern Rockies (Arizona, Colorado, Nevada, Utah and Wyoming). We propose that camper movement of firewood is a high risk pathway of non-native organisms within and into western states, especially if campers come from infested areas.

In 2009 we conducted personal interviews and quantified the number of campers visiting 30 campgrounds in 13 national parks and national recreation areas in the southern Rocky Mountain region. We visited 4,522 campsites and personally surveyed 1,658 camper groups, asking voluntary questions pertaining to their sources of firewood. Preliminary results indicate that 1,116 campers surveyed had firewood (68% of all campers) and 36% had firewood from outside the park state. When weighted by park camping visitation numbers, this equates to 330,575 incidents in 2008 of campers bringing out-of-state wood into the parks surveyed. Results varied by state: 23% of campers in Arizona parks brought firewood from outside the state, 8% in Colorado parks, 43% in Nevada parks, 57% in Utah and 24% in Wyoming. Of campers with firewood, 32% of the firewood was purchased inside the park, 25% was purchased outside the park and 17% was cut or collected from the camper's home. Fifty-three percent of firewood had the presence of previous insect infestations while 39% had fungal contamination (primarily blue stain fungi). Future movement of non-native pests might be prevented if we can manage and restrict the movement of infested wood, particularly firewood.

non-native insects, fungal pathogen survival, exotic insects, risk assessment, forest pests, firewood

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Jason Janke
Metropolitan State College of Denver
Jjanke1@mscd.edu

Patricia Dienstfrei
Metropolitan State College of Denver

Karey Grant
Metropolitan State College of Denver

Temperature Signature Indicators of Permafrost along Trail Ridge Road

Although GIS models have been developed to map alpine permafrost occurrence, their results are often generalized and in some instances have been validated based on limited field data. A field monitoring network of 30 HOBO temperature data loggers was installed at unique sites along Trail Ridge Road during the summer of 2008. Each logger contains a temperature sensor at 10 cm below the surface and a second sensor at depths ranging from 30 to 80 cm. Temperatures were recorded at two-hour intervals over the course of a year. The Mean Annual Soil Temperature (MAST) at 10 cm was below freezing for 28 of the 30 sites. At 10 cm depth, the MAST was -1.1°C for all sites; at secondary depths ranging from 30 to 80 cm, the MAST was also -1.1°C but had a lower standard deviation. December to February means were -8°C at 10 cm and -6°C at depth. Frost indices averaged 0.56 at the surface, which indicates that sporadic permafrost is present. The active layer likely extends some one to three meters below the surface where permafrost is present. During the early autumn, several sites had "zero curtain" signatures where temperatures at each probe remained at 0°C for an extended period. This suggests convergence of the upward (from the permafrost below) and downward (from the atmosphere above) freezing fronts; constant 0°C temperatures are produced as large quantities of latent heat are released. Some sites exhibited a spring snowmelt signature in which deeper probes have extended period during which the temperature is constant at 0°C after the near surface probe rises above freezing. This likely indicates the flow of snowmelt groundwater at a depth along a "wet line" on the permafrost surface.

permafrost, geographic information systems (GIS), climate change, Trail Ridge Road

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Amanda Jeter
University of Colorado Denver
mandajet@gmail.com

Change Over Time: Design Evolution of Timber Creek and Aspenglen Campgrounds

Influenced by research of historical National Park Service drawings and field work, this presentation will document the design evolution of two campgrounds in Rocky Mountain National Park: Timber Creek and Aspenglen Campgrounds. Campground design has evolved with the

changing philosophies of the National Park Service during the Great Depression and Misson 66 eras. The campgrounds have also faced ecologic disturbances including the mountain pine beetle and flooding. The philosophies behind the layout, circulation, furnishings and amphitheatres will be discussed for each campground. An investigation into the current design philosphy of the National Park Service in the face of ecologic disturbance will also be presented.

Landscape Architecture, National Park Rustic Style, Timber Creek Campground, Aspenglen Campground, ecological disturbance and design solutions, Civilian Conservation Corps

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Kristen M. Kaczynski
Colorado State University
kristen.kaczynski@colostate.edu

David Cooper
Colorado State University

William Jacobi
Colorado State University

Willow Decline in Rocky Mountain National Park: Examining the Interactions of Drought, Ungulate Browsing, Sapsuckers, and Fungus

Willows are critical components of Rocky Mountain riparian ecosystems, particularly within Rocky Mountain National Park, where they provide the majority of the woody vegetation. They provide food for ungulates and beavers; habitat for resident and migratory bird populations, and amphibians; and are integral components of the structure and function of montane riparian ecosystems. However, willow communities in the Rocky Mountains have changed dramatically over the past 15 years. Previous researchers have analyzed the effects of elk browsing on willow communities, as well as the altered hydrologic regimes due to reduced beaver populations on willow decline. However, there likely are several other key factors and processes which are contributing to and interacting with these known factors causing declines in willow populations, including plant infection by *Cytospora spp.* fungi and temperature induced late-season drought. Field work initiated in the summer of 2009 examined willows within the Kawuneeche Valley, where dieback is widespread. Preliminary analysis has shown that willow canopies within this valley have declined over 65%. Our primary goal is to identify a cause of the willow dieback, and we will use seasonal changes in willow populations and controlled and replicated experiments to examine morphological, physiological, and pathological changes in plants over the growing season, and throughout the year. Results will provide information to inform park managers on the timing and causes of this decline, and could identify concepts for use in riparian recovery and restoration efforts.

Salix sp., riparian communities, drought, ecosystem stressors, elk, fungus

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Ken Kaliski
Resource Systems Group Inc.
kkaliski@rsginc.com

Adam Gibson
Colorado State University

Steve Lawson
Resource Systems Group Inc.

Modeling and Mapping Transportation-Related Noise Impacts in Protected Natural Areas

Over the past several years, the technology for creating noise maps covering large geographic areas has significantly advanced. The European Union now uses noise mapping to assess the exposure of their communities to unhealthy noise levels. In the same way, national parks can use noise maps to predict the exposure of their visitors to human-induced noise. In one of the first significant application to vehicular noise in a U.S. national park, Rocky Mountain National Park is using noise mapping to assess the change in noise exposure resulting from various transportation planning options. The project includes background sound level monitoring to assess existing conditions, model calibration, and computer modeling of transportation noise for various bus and parking scenarios over a 20,000 acre area. This information is integrated with visitor use models to estimate the number and location of people that could be exposed to various levels of transportation noise.

noise impacts, vehicles, visitor use

Stephanie Kampf
Colorado State University
skampf@warnercnr.colostate.edu

Julie Markus
The Ohio State University

Jared Heath
Colorado State University

Paul Ackerman
Colorado State University

Jill Baron
U.S. Geological Survey

Snowmelt and Soil Moisture Distributions on Two Subalpine Hillslope Transects

Melting of the seasonal snow pack provides the dominant source of moisture to soils and vegetation in the subalpine zone, yet we have limited measurements that help monitor pathways of melt water. The objective of this research is to determine controls on snow melt and soil moisture distributions on forested subalpine hillslopes in the Loch Vale watershed. The study is conducted on two hillslope transects, each 200 m long with an average vertical gradient of 30%. One transect faces northeast, and the other faces east. Both transects have patchy forest cover of Engelmann spruce and subalpine fir. We measured snow depth and surface soil moisture at 10 m increments along these transects during the summers of 2008 and 2009. During both years, snow cover persisted through most of June, with snow-free areas appearing first below tree clusters and near streams. The transects were snow-free by the end of July in both years. Spatial variability in soil moisture appeared to be unrelated to the spatial variability in snow. Surface soil moisture at individual points on the hillslopes showed gradual drying throughout the summer, with occasional re-wetting during summer rain events. Analyses of moisture patterns suggest that soil moisture distribution on these slopes is controlled by the strong topographic gradient and high input of melt water, which travels downslope via shallow subsurface flow. On northeast-facing slope, some of the subsurface flow exfiltrated at slope breaks or along soil-bedrock interfaces to produce overland flow. Surface soil moisture stayed above field capacity in almost all slope locations during summer 2008, but in 2009, parts of the east-facing slope dried to below field capacity by the end of August.

hydrology, soil moisture, snow, Loch Vale

Cori Knudten
Colorado State University
coriknudten@yahoo.com

A Diminishing Shadow: Longs Peak and Auto Tourists in Postwar Rocky Mountain National Park

Longs Peak, the highest mountain in Rocky Mountain National Park, occupies a distinct cultural space. Through the 1950s, Longs Peak was presented as a mountain that all tourists—including auto tourists—could and should climb. In the postwar era, however, Longs Peak receded from auto tourists' experience of the park and became part of a wilderness area reserved for serious hikers and climbers. This presentation explores how the cultural role of Longs Peak changed over the years as a result of park management decisions and changing conceptions of wilderness and national parks. The presence of auto tourists in the park and debates about the legitimacy of their experiences initiated many of the changes in the space of Rocky Mountain. Through the influence of the Mission 66 program and national debates about wilderness, the space of Rocky Mountain fragmented. Longs Peak became part of a space conceptualized as wilderness and out of the reach of auto tourists.

automobile tourist, wilderness, Longs Peak, history

Natalie Kramer
Colorado State University
nkramer@lamar.colostate.edu

Characterizing the Valley Fill in Beaver Meadows, Rocky Mountain National Park

Little is known about the magnitude of sediment accumulation in glacial troughs post retreat of the Pleistocene valley glaciers in the Rocky Mountains of northern Colorado. This study uses ground penetrating radar (GPR), near surface seismic refraction and augering to determine the depth and to characterize the stratigraphy of valley fill in Beaver Meadows. During the summer of 2009, around 5km of GPR data and 1km of seismic data were collected along with cores from 23 sites dug with a 2m hand auger. Preliminary analysis of suggests that the total valley fill not associated with glacial deposition is less than seven meters thick. A low volume of valley fill in Beaver Meadows implies that instead of accumulating a complete post-glaciation sediment record, the valley only filled to a certain level, possibly controlled by a baselevel set at the mouth. This means that once the valley was filled, sediments were transported to the non-glaciated canyon below at the same rate in which they were deposited. Instead of thinking about glacial troughs as sites of steady sediment accumulation, perhaps they are better thought of as conveyor belt of sediments. How much impact beaver damming may have had on trapping and transporting the

sediment downstream in this type of scenario has yet to be examined and may have management implications concerning the re-introduction of the beaver.

ground penetrating radar, GPR, seismic refraction, Beaver Meadows, valley fill, glaciation, sedimentation, beavers, stratigraphy, glacial trough

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Sean P. Maher
University of Kansas
maher@ku.edu

Tony Schountz
University of Northern Colorado

Robert M. Timm
University of Kansas

A. Townsend Peterson
University of Kansas

Does Landscape Matter to Disease Prevalence and Occurrence?

Landscape patterns of distributions of organisms have been well-documented, and now recent studies have described the landscape effects on disease systems. Sin Nombre virus, the cause of Hantavirus Pulmonary Syndrome, occurs naturally in Deer Mice (*Peromyscus maniculatus*), a species that is nearly ubiquitous in much of North America. Infection in this host generally does not cause mortality, and is passed among individuals through physical contact. This pathogen has been studied in depth at local scales, but the dynamics across relatively contiguous landscapes or environmental gradients have not been documented. Plague, caused by the bacterium *Yersinia pestis*, occurs in western North America in a variety of mammal taxa, and is spread by flea vectors. Infection is generally fatal, and plauge is maintained in epizootic and enzootic cycles.

We sampled seven sites in 2007 and 2008 along an elevational gradient in Colorado to ask whether host and pathogen dynamics were detectable at local landscape scales, and if virulence affected these dynamics. Our survey showed low levels of hantavirus infection and failed to detect plague in either hosts or vectors. Landscape connectivity metrics and patterns of host richness and diversity did not correlate with hantavirus prevalence. Our data suggest that this landscape may not impose differences with regards to hantavirus, although we acknowledge the definite possibility of Type II error.

Hantavirus, plague, fleas, small mammals

James H. McCutchan, Jr.
University of Colorado
james.mccutchan@colorado.edu

Cheri Yost
Rocky Mountain National Park

Leigh A. Cooper
University of Colorado

Thomas M. Detmer
University of Colorado

The Rocky Mountain National Park WaterBlitz: Two Mid-Summer Snapshots of Water Quality

The chemical composition of stream water reflects patterns of atmospheric deposition, mineral weathering, nutrient uptake, and human activities. Spatial variation in water quality also can affect the distribution and abundance of stream organisms, including algae, aquatic insects, and fish. In order to capture snapshots-in-time of water quality across Rocky Mountain National Park, National Park Service staff, volunteers, and researchers at the University of Colorado collected almost 200 stream-water samples on a single date in August, 2008 and again in August, 2009. Water samples were analyzed for pH, nutrient concentrations, and a variety of other water quality parameters. Photos taken at each sampling location provided information on the stream channel and riparian zone at each location. Water chemistry varied with stream size and elevation, but forest disturbance also has affected spatial patterns of stream-water chemistry across Rocky Mountain National Park. Differences in precipitation patterns resulted in some differences in water chemistry between 2008 and 2009, but spatial patterns were generally similar between the two years. This study provides a baseline for evaluating future changes in water quality across Rocky Mountain National Park and also will aid in the design of new research projects and monitoring programs.

stream water chemistry, nutrients, spatial variability, mountain pine beetle

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Kristen Meyer
Affiliation at the time of the project: Colorado State University
kemeyer@fs.fed.us

Assessment of the Breeding Bird Monitoring Program at Rocky Mountain National Park

Rocky Mountain National Park implemented 13 years of a habitat-based monitoring program to track population trends of breeding birds. Data were collected using multiple point transects and from 2000 to 2006, incorporated distance sampling methodology. An important part of an effective monitoring program is continually evaluating the effectiveness of survey methods and

making appropriate changes based on that information. The methodology of the park's breeding bird monitoring program was evaluated in 2000; however, this is the first time that the data were analyzed for annual trends in estimated densities. The Rocky Mountain Bird Observatory (RMBO) collected 10 years of data throughout the state of Colorado using similar distance-sampling methods to those employed by the park and will continue these monitoring efforts into the future. In order to assess if RMBO data could be used for management planning in the park, annual densities were estimated for each year from 2000 to 2006 for the park and compared to breeding bird data collected for the state of Colorado by RMBO. Trends in annual density estimates were not evident in the park data for all of the species because the confidence intervals overlapped across many of the years. There were also no clear differences between the park and RMBO data for most species in most habitat types due to overlapping confidence intervals between the two datasets. Four species in high-elevation riparian habitat showed different densities in the park data than the statewide data, while seven species in ponderosa pine habitat had larger densities in the park data than the statewide data. Although a distinct comparison between the two datasets was inconclusive, the results of this study provided information to make future monitoring recommendations for selecting optimum time intervals, targeting indicator species, increasing sample sizes, and improving data quality.

breeding birds, monitoring, Rocky Mountain Bird Observatory

Chris Monz
Utah State University
chris.monz@usu.edu

Ashley D'Antonio
Utah State University

Quantifying the Natural Resource Consequences of Day Use in Rocky Mountain National Park

Understanding the natural resource consequences of visitor use in parks is essential for avoiding the impairment of park resources and visitor experiences. In particular, visitor use in areas off hardened trails can result in rapid and significant change in resource conditions. This research reports on a the ecological component of the larger study entitled "Modeling the Effects of Alternative Transportation on Resource Protection and Visitor Experiences in Rocky Mountain National Park." The project focused on the Bear Lake Road corridor as a discrete system of the park where transportation, visitor use, visitor experience and resource impact could be assessed and modeled. An overall goal of this project was to integrate these components to the greatest degree possible in order that likely consequences of alterations in visitor flows on visitor experiences and park resources could be examined. Specifically, the ecological component of the project examined backcountry areas where resource change as a result of visitor activities off designated trails and sites was evident. The vast majority of this impact was from day use visitors engaged in hiking, fishing and climbing activities. Standard procedures were used to assess visitor-created sites and informal trails, while new methodologies were developed to assess larger areas of more diffuse resource impact. Results suggest that visitor-created resource impacts were prevalent and intense, but were somewhat spatially limited to areas around destination sites (lakes, view sites, etc.) and established trail corridors. Social trailing was particularly prevalent, in many areas exceeding the system (designated) trails in total linear extent. Areas of diffuse visitor use surrounding Alberta Falls and Emerald Lake were assessed and modeled to determine the distribution of sensitive groundcover and current and potential visitor use levels and patterns off designated trails.

Bear Lake Road corridor, visitor use, resource impacts

Kellen N. Nelson
Colorado State University
knelson@warnercnr.colostate.edu

Monique E. Rocca
Colorado State University

Carissa F. Aoki
Colorado State University

Matt B. Diskin
Colorado State University

William H. Romme
Colorado State University

Mountain Pine Beetle-Related Lodgepole Pine Mortality: Multi-Scale Causes and Effects in Rocky Mountain National Park, CO

An ongoing mountain pine beetle outbreak has been dramatically changing Colorado's lodgepole pine forests since 1996. Warmer climate trends and extensive old forests facilitated this widespread outbreak. We distributed 46 randomly located clusters of three plots across the west side of Rocky Mountain National Park to examine the influence of environmental and stand structure factors on lodgepole pine mortality patterns, and to assess changes to stand and landscape structures through three stages in the eruption. Across the landscape, mean stem mortality reached 47%; however, 71% of basal area was killed. Surviving stand structure experienced large decreases in diameter at breast height (17.4 to 11.0 cm), basal area (29.3 to 8.5 m^2 ha^{-1}), and density (1393 to 915 stems ha-1). Environmental factors (elevation and moisture) and tree size greatly influenced which stands saw high levels of mortality during the early stage of the eruption. In contrast, later stages of the eruption showed stronger relationships with stand structure factors (tree size, basal area, proportion of non-host trees, density and stand age). Changes in forest heterogeneity depended on spatial scale. At the local scale, heterogeneity increased within forest stands, while heterogeneity among stands on the landscape declined over time. The current mountain pine beetle outbreak has caused extensive changes to the subalpine forest landscape, but high densities of surviving trees and increased stand-scale heterogeneity will allow forest recovery and increased resistance in the face of future outbreaks.

insect and disease outbreaks, mountain pine beetle, lodgepole pine, heterogeneity, cross scale interactions (CSI)

Kellen N. Nelson
Colorado State University
knelson@warnercnr.colostate.edu

Monique E. Rocca
Colorado State University

Aspen Sucker Density and Growth Following Mountain Pine Beetle-Related Mortality in Rocky Mountain National Park

The mountain pine beetle (MPB) eruption in Rocky Mountain National Park is causing extensive mortality of lodgepole pines and may reduce competitive pressure on aspen. We assessed the effect of MPB-related mortality on aspen regeneration by examining whether sucker densities and growth rates increase with MPB-related mortality, and if ungulates utilize additional suckers through browsing. Heavy lodgepole pine mortality reduced conifer basal area by 80% and stem density by 50% of pre-eruption levels. This appears to relieve competitive pressure on aspen in mixed lodgepole pine-aspen stands. Linear mixed effects model results show that as mortality increases, aspen sucker density increases three-fold, aspen stem elongation doubles, and mean sucker height increases by two-thirds. Additionally, sucker density does not appear to be correlated with ungulate browsing rates. MPB-related mortality relieves conifer pressure and may lead to successful aspen recruitment.

aspen, lodgepole pine, mountain pine beetle, succession, competition

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Peter Newman
Colorado State University
Peter.Newman@colostate.edu

Steve Lawson
Resource Systems Group Inc.

Chris Monz
Utah State University

Robert Chamberlin
Resource Systems Group Inc.

Larry Gamble
Rocky Mountain National Park

Ken Kaliski
Resource Systems Group Inc.

David Pettebone
Yosemite National Park

Ashley D'Antonio
Utah State University

Derrick Taff
Colorado State University,

Adam Gibson
Colorado State University

Ben Swanson
Resource Systems Group Inc.

Logan Park
Southern Illinois University

Karen Hockett
Virginia Polytechnic University

Research to Support Implementation of Integrated Transportation Planning and User Capacity Decisions in Rocky Mountain National Park

Rocky Mountain National Park's Bear Lake Road corridor has a high degree of visitor access. With many visitors accessing the Bear Lake area via the shuttle bus, rather than private vehicles, the constraint to visitor use levels associated with parking lot capacities has been eliminated. The park is now re-evaluating transportation alternatives. This paper provides an overview of a study conducted in 2008-09 with five integrated components: 1) modeling of private and transit vehicle traffic in the Bear Lake Road, 2) modeling of visitor use at selected recreation sites serviced by the Bear Lake shuttle bus, 3) assessing resource impacts at selected recreation sites serviced by the Bear Lake shuttle bus, 4) conducting visitor survey research (perceptions of crowding, ecological impacts, and beliefs about Leave No Trace practices) at selected recreation sites serviced by the Bear Lake shuttle bus and 5) developing an acoustic model for the Bear Lake Road corridor that predicts potential visitor exposure to transportation noise. Information will inform future park management actions in the Bear Lake Road corridor, and also provides a model for studies related to alternative transportation on public lands.

Bear Lake Road corridor, visitor impact, visitor use, visitor perceptions, alternative transportation

Brooke B. Osborne
Colorado State University
bosborne@nrel.colostate.edu

Jill S. Baron
U.S. Geological Survey

Matthew D. Wallenstein
Colorado State University

Eric E. Richer
Colorado State University

A Survey of Alpine Microbial Community Response to Climate Change and Atmospheric Nitrogen Deposition

Remote United States western alpine ecosystems exhibit vulnerability to anthropogenic drivers of change. Atmospheric nitrogen (N) deposition and unprecedented rates of climate-induced deglaciation add nutrients, alter hydrologic processes, and expose soils to primary succession. We cannot yet predict the far-reaching biogeochemical consequences of this influence. Importantly, long-term data reveal unexpected increasing trends in headwater nitrate (NO3-) concentrations of > 50% from the 1990s to 2006 along the Colorado Front Range. Such dramatic changes in nutrient cycling raise concern for oligotrophic alpine lake environments due to the heightened possibility of eutrophication. Increasing stream nitrate suggests an important role of microbes in nitrifying ammonium from atmospheric deposition and potentially a general increase in microbial activity stimulated by warmer temperatures. My upcoming study will characterize local microbial communities and investigate potential microbial linkages between glacier melt, N deposition, and changing NO3- concentrations. We are currently analyzing long-term Forest Service data to select up to eight high elevation catchments demonstrating clear increasing, decreasing, or stable trends in NO3- concentration. Site selection will take glacier or rock glacier presence or absence into account. Overlaying N deposition and glacier cover maps demonstrating change through time will enable cross-site spatial comparison. Relative microbial abundance and functional group activity

will be evaluated directly in soil samples in addition to a series of laboratory temperature and N amendment assays.

nitrogen, climate change, alpine catchments, nitrogen deposition

Sara J. Oyler-McCance
U.S. Geological Survey
University of Denver
sara_oyler-mccance@usgs.gov

Jennifer A. Fike
U.S. Geological Survey
University of Denver

Tena Engelman
Rocky Mountain National Park

Fred C. Engelman
Rocky Mountain National Park

Investigation into Family Relationships among Broad-Tailed Hummingbirds using Molecular Genetic Techniques

The broad-tailed hummingbird (*Selaphorus platycercus*) breeds at high elevation and has been studied for many years in Rocky Mountain National Park. Previous observations and circumstantial evidence led to the hypothesis that adult female broad-tailed hummingbirds remain with recently fledged young for weeks or longer after fledging and that some females captured and banded in close time proximity and then returning in later years to be captured again in close time proximity might be related (i.e., mother and daughter). To investigate this hypothesis, we developed 12 polymorphic microsatellite loci and modified previously developed sexing primers. Preliminary data suggested that DNA from single feathers does not contain a sufficient quantity of DNA to accurately genotype and sex broad-tailed hummingbirds. Consequently, we extracted DNA from muscle tissue from one female and one male broad-tailed hummingbird. Then from these same individuals, we extracted DNA from one to six feathers to determine how many feathers were necessary to accurately genotype and sex individuals. We found that extracting DNA from two to three feathers sampled from a single hummingbird provided sufficient DNA to accurately genotype and identify the sex of broad-tailed hummingbirds in question. This methodology will now be used to genotype and sex broad-tailed hummingbirds captured in Rocky Mountain National Park and to determine whether groups of individuals thought to be related truly are parent and offspring.

broad-tailed hummingbird, Selaphorus platycercus, DNA, microsatellites, family relationships

David Pettebone
Yosemite National Park
David_Pettebone@nps.gov

Peter Newman
Colorado State University

Exploring Visitor Preferences for Transportation Options in Rocky Mountain National Park

Stated choice analysis was used to assess visitor's preferences various modes of transportation including personal vehicles versus park shuttle busses. Visitor's were asked to choose which transportation option they preferred to use along the Bear Lake road in Rocky Mountain National Park based on destination convenience, vehicle traffic volume, visitor volume(by transportation mode), and probability of solitude. Results provide insight into visitor preferences concerning the management of transportation systems in busy national parks like Rocky Mountain. Results suggest that visitor's prefer to drive their personal vehicles but would use the park's shuttle system to avoid traffic congestion along roadways or crowding along the trail.

Bear Lake Road corridor, visitor preferences, shuttle bus

Covey Potter
Colorado State University
coveyp@gmail.com

David Cooper
Colorado State University

Designing a Restoration Protocol for a Degraded Wetland Complex at the Headwaters of the Colorado River in Rocky Mountain National Park

The headwaters of the Colorado River in Rocky Mountain National Park have been adversely affected by the Grand Ditch for 120 years. The Grand Ditch diverts nearly 50 percent of water tributary to the Colorado River headwaters within the park. In 2003 a breach of the Grand Ditch inundated Lulu Creek, several kilometers of Colorado River channel and adjacent floodplains, and the Lulu City wetland with more than 45,000 cubic yards of sediment and debris. The integrity and functionality of the Colorado River is of great social, economic, and ecological importance. From the park the Colorado River flows 2,330 km to the Gulf of California providing water resources, fishery stocks, wildlife habitat, and intrinsic socio-ecological value. The objective of our research is to design a restoration and management plan for the Colorado River headwaters incorporating current and historic groundwater levels, riparian vegetation composition, post breach sediment thicknesses and volumes, historic channel morphology, and flow regimes. In 2009 we selected

four reference reaches comparable to areas affected by the breach. Vegetation surveys determined suitable species for restoration. Groundwater levels were monitored using 97 PVC wells and eight digital data loggers. A total of 51 pit excavations demonstrated soil stratigraphy and thickness of post breach sediment layers and buried vegetation. The breach in 2003 was not the first Grand Ditch caused debris event. Historic photo analysis and pit excavations expose several catastrophic debris events. Increased sediment thickness has elevated the landscape consequently lowering the water table. Obligate riparian vegetation such as *Carex utriculata*, *Salix drummundiana*, *S. monticola*, and *Alnus tenuifolia* have been replaced by typical upland species *Pentaphylloides floribunda*, *Abies bifolia*, and *Picea engelmannii*. Our data help characterize a region adversely impacted by altered hydrologic flow, aberrant sediment deposition, and incongruous vegetation composition. Continued research will yield key insights into the steps necessary to implement suitable restoration and management.

restoration, wetland, Colorado River, debris flows, Grand Ditch

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Jenny Powers
National Park Service, Biological Resources Management Division
Jenny_Powers@nps.gov

Margaret Wild
National Park Service, Biological Resources Management Division

Terry Spraker
Colorado State University

Mark Graham
New River Gorge National River

Mike Miller
Colorado Division of Wildlife

Utility of Rectal Biopsy for Preclinical Diagnosis of Chronic Wasting Disease in Free-Ranging Rocky Mountain Elk

Chronic wasting disease (CWD) has not previously been diagnosed using a preclinical ante mortem test in free-ranging elk (*Cervus elaphus nelsoni*). In this study, we captured, radio collared, and collected samples of rectal lymphoid tissue from 136 female elk in Rocky Mountain National Park. No clear clinical signs of CWD were observed at the time of capture. Thirteen of 117 diagnostic samples (86% diagnostic using ≥ 5 lymphoid follicles) were positive when examined using immunohistochemistry. Positive animals were removed from the population and complete necropsies performed. All had evidence of PrPCWD in the brain and retropharyngeal lymph nodes. Three months post-capture, a single CWD biopsy test negative female began showing subtle behavioral signs of disease. At necropsy she was confirmed CWD positive, and represents an apparent false negative rectal biopsy result. In January 2009, one year post capture, 20 study animals were observed, darted and repeat rectal biopsies were performed prior to being euthanized. None demonstrated clinical signs of CWD at this time. In 2009, 75% of biopsies contained ≥ 5 lymphoid follicles, and one animal was rectal biopsy and brain/ lymph node CWD positive. Full necropsy results are pending from this cohort. These results show that rectal biopsy can be used to diagnose preclinical CWD in free-ranging elk and may provide a method for measuring CWD incidence if repeated at regular intervals; however, it is currently unknown at what point in the disease course rectal tissue accumulates CWD positive prion. Therefore, additional information to be gathered in 2010-2011 will give a more complete understanding of the utility of rectal biopsy as a management tool.

Chronic wasting disease, CWD, elk, biopsy, diagnostic test

Sara L. Rathburn
Colorado State University
rathburn@cnr.colostate.edu

Zan K. Rubin
Colorado State University

Ellen E. Wohl
Colorado State University

Quantifying Fluvial Processes along Lulu Creek and the Colorado River: Planning for River Restoration in Rocky Mountain National Park

Water discharge and sediment transport over the snow melt runoff season has been collected for five years within the Upper Colorado basin following the 2003 Grand Ditch breach. More frequent and accurate measurements were collected during 2008 and 2009 with the installation of eight recording stream gauges along sample cross sections and reference reaches. Discharges from Grand Ditch into Lulu Creek are highly variable and unpredictable, controlling sediment transport in Lulu Creek and the Colorado River. Rapid stage changes of 20 cm have been measured in the Colorado River, resulting in pulses of flow that entrain and transport sediment. Releases from the Ditch at reservoir capacity have been quantified and provide insight into a more natural flow regime. Since 2003 the peak flow measured in the Colorado River is 3.0 m3/s, a discharge below morphologic bankfull. Suspended and bedload sediment flux is greatest at the downstream-most sample cross section, with a maximum of 3.4 m3/day and 4.5 m3/day of suspended load and bedload sediment, respectively, in transport toward the Lulu City wetland. Grain size analyses of bedload indicate a general fining of bedload in transport in the downstream direction, with an overall fining then coarsening of grain sizes over snowmelt. Pebble counts of bed material at the

sample cross sections show a localized increase in grain size at a narrow point in the Colorado River valley. Local coarsening at this site is corroborated by an increase in size of a mid-channel bar and measured bed aggradation. Additional pebble counts will reveal whether or not there is a local control on sediment transport and bed aggradation, or whether the coarsening indicates a trajectory towards stability and bed armouring. Cross section resurveys indicate sediment is preferentially evacuated from the Lulu Creek fan, with minor sediment removal along the Colorado River.

fluvial processes, discharge, suspended and bedload transport, river restoration, Grand Ditch

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John D. Ray
National Park Service, Air Resources Division
John_D_Ray@nps.gov

Ozone Health Warnings and the Spatial Distribution of Ozone in the Park

Ozone air pollution is well known to cause human health problems and to harm vegetation. Although ozone is monitored on the east side of the park, the transport and distribution of ozone within the park is not well known. As a result, there is some uncertainty as to where the health warnings should apply when the ozone concentrations are measured or forecasted to be in the unhealthy ranges. Ozone forecasts for the Denver Metro Area have been found to be inappropriate for park warnings. Yet, air pollution from the Front Range does transport to the park on some days. Information on the transport and conditions when poor air quality is likely to happen will be presented. Higher elevations in the park are more likely to have persistent ozone concentrations during the summer that are punctuated by a few events. The eastern side of the park sees similar ozone concentrations as the monitor, while the western side of the park sees lower concentrations. Long range transport and high ozone concentrations related to wildfires have also been observed. Some ways to improve on the ozone forecasting and to better communicate the extent of poor air quality conditions within the park during the summer will be suggested.

ozone, air pollution, air quality, transport and formation, forecasting, human health, haze

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Eric Richer
Colorado State University
eericher@nrel.colostate.edu

Jill Baron
U.S. Geological Survey

David Clow
U.S. Geological Survey

Matt Layden
U.S. Geological Survey

Proposal for Wind Generators at the Loch Vale National Atmospheric Depositional Program Site and Andrews Creek Weather Station in Rocky Mountain National Park

Research on the effects of atmospheric deposition and climate variability on ecosystem processes and watershed hydrology has been ongoing in the Loch Vale watershed since 1982. The operation of monitoring equipment including precipitation collectors and meteorological stations is vital for achieving research and management objectives. In addition, the Loch Vale National Atmospheric Depositional Program (NADP) monitoring site is being used to evaluate effectiveness of the Colorado Nitrogen Deposition Reduction Plan. Research equipment in the Loch Vale watershed is currently powered by battery banks and solar panels. Due to limited winter time exposure to solar radiation, solar panels have proved insufficient for meeting power requirements at monitoring sites. Power loss leaves research equipment inoperable and jeopardizes both data completeness and quality. Due to seasonal variability in solar and wind resources, hybrid systems that utilize both solar photovoltaic panels and a wind turbine are the most effective way to ensure a continuous power supply for data collection in remote mountainous terrain. We propose the installation of small wind generators at monitoring sites within the Loch Vale Watershed to supplement solar generated power during winter time operation.

Loch Vale watershed, atmospheric deposition, NADP, wind generator, solar panels, solar panels

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Tobias Riede
University of Utah
t.riede@utah.edu

Ingo R. Titze
University of Utah
University of Iowa

Anatomy and Physiology of Elk Bugling

A number of interconnected size-dependent factors make small mammals apt to produce high acoustic frequencies, while large mammals generally are specialized toward lower frequencies. Rocky Mountain elk and European red deer are closely related but their male vocal mating displays are very different. The red deer produces low pitched roaring sounds, and the Rocky Mountain elk utters high pitched bugle calls. In both species the direct investigation of physiological aspects of sound production is difficult. We have therefore studied selected anatomical and physiological aspects in both species and developed a computer simulation of a vocal organ and compared the computer sound simulations with natural elk and red deer vocalizations. Tissue was available from hunter-harvested elk submitted to the Colorado Division of Wildlife's chronic wasting disease surveillance program and from farmed red deer. Sound recordings of elk were conducted in Rocky Mountain National Park and in Mueritz National Park, Germany. The computer model produces a large fundamental frequency range of self-sustained vocal fold oscillation, but with vastly different muscle activation and tissue strains. Results suggest that both cervid species use vocalization at high lung pressure, suggesting that metabolic cost was high in either case. Quite interesting is that the production of high fundamental frequency calls provides an efficiency advantage. To produce a high frequency call the glottal area is much smaller leading to a smaller airflow through the glottis. Consequently the aerodynamic power required is smaller in the high frequency call. Calculations mark an efficiency advantage of approximately five for the high frequency call, based on a better radiation of higher frequencies from orifices, and a two-fold reduction in aerodynamic power. The model is also able to simulate numerous acoustic features typical for the natural phonation in elk and red deer.

elk, European red deer, bugle, sound frequency

Tobias Riede
University of Utah
t.riede@utah.edu

Kenneth K. Jensen
Indiana University

Ole N. Larsen
University of Southern Denmark

Keith Attenborough
University of Hull

Shahram Taherzadeh
The Open University

Habitat Acoustics of Rocky Mountain Elk in Colorado and European Red Deer in Denmark

Male vocal displays are rarely so dramatically different in closely related subspecies as in *Cervus elaphus.* Many studies have investigated the evolution of the European red deer low pitched roaring sounds, but little is known about why the Rocky Mountain elk evolved high pitched bugles. We investigated whether sound attenuation characteristics in their respective habitats might have contributed to the evolution of these very different vocal displays. We tested two hypotheses in two representative habitats, the Rocky Mountain National Park, and the Vejers Klitplantage Nord, Denmark.

Sound attenuation is frequency dependent. We tested the attenuation pattern of playbacks of a harmonic complex consisting of frequencies up to 6 kHz over various distances. Results suggest, first, that in Denmark a more pronounced low frequency (up to 1 kHz) attenuation occurs, and, second, the variance for a small frequency window around 2 kHz is smaller in Colorado.

Attenuation depends also on the ground effect. The ground effect is the acoustic interference between the direct sound wave from sender to receiver and the indirect sound wave reflected off the ground. The effect depends on acoustic properties of the ground and can result in severe attenuation of sounds in particular at lower frequencies. We tested whether Colorado soil is acoustically softer than European soil, negatively affecting low frequencies propagation. We found the opposite true. The smaller ground impedance in Denmark is the likely explanation for the stronger low frequency attenuation. However, ground impedance differences are so small that they hardly can account for a strong selective pressure against low frequencies in Colorado.

In summary, our data suggest that frequency-dependent attenuation and ground effect are unlikely candidates supporting higher frequency calls in North America. The smaller variance around 2 kHz, although not consistent, seems currently the only observation favoring a high pitched vocalization.

elk, European red deer, bugle, sound frequency, acoustics

Aaron P. Roberts
University of North Texas
Aaron.Roberts@unt.edu

Matthew J. Kovach
University of North Texas

Benjamin Barst
University of North Texas

Karista Hudelson
University of North Texas

James Smith
University of North Texas

Barney J. Venables
University of North Texas

William T. Waller
University of North Texas

Plankton and Planes: Pigment Control in Alpine Copepods

Phenotypes of a freshwater zooplankton (*Diaptomus shoshone*) sampled from alpine and subalpine lakes range in color from red to blue including transitional stages. Although accumulation of carotenoids is known to correlate with increased ultraviolet tolerance in alpine copepods, the physiological mechanisms and ecological tradeoffs involved in extreme color change are not well understood. Understanding these mechanisms and how they may be affected by environmental change is important due to the role of copepods and carotenoids in alpine lake food webs. The purpose of this project is to examine esterification and protein binding as a means of pigment control in alpine copepods. We sampled populations of alpine copepods from different lakes at elevations ranging from 9,500' to 12,700' in the Front Range of the Colorado Rocky Mountains. Carotenoids in each population were analyzed using high pressure liquid chromatography (HPLC) and found to vary among populations and phenotype. Caroteno-proteins were isolated from individual populations of copepods and color change manipulated ex vivo using protein denaturation (irreversible) and pH (reversible). A histological examination of pigment deposition was also carried out. Based on some of these findings, we hypothesize that control of carotenoid metabolism may be closely tied to reproduction. Results of these studies have important implications for the physiological ecology of the organisms as well as bio-inspired materials research.

copepods, freshwater zooplankton, carotenoids, pigments

Zan K. Rubin
Colorado State University
zan@lamar.colostate.edu

Sara L. Rathburn
Colorado State University

Ellen E. Wohl
Colorado State University

Innovative Methods to Investigate Historic Processes and Provide Context for the Restoration of Lulu City Wetland, Rocky Mountain National Park

Stream and wetland restoration projects must seek to integrate understandings of contemporary and historical physical processes as well as ecological dynamics. This understanding can provide context for restoring ecosystem functions rather than simply imitating past landforms. Ultimately, restoration must not seek to benefit specific species or reconstruct landforms without understanding the supporting processes.

In 2003, a breach in Grand Ditch initiated a debris flow in Rocky Mountain National Park that transported ~36,000 m^3 of sediment into the Upper Colorado River and deposited up to 75 cm of sediment in Lulu City wetland. Aerial photos dating back to 1937 show several prior ditch failures and several depositional events in the wetland, suggesting an altered sediment regime that has persisted for at least 70 years. No earlier images of the Lulu City wetland are known to exist. Prior geomorphic and ecologic impacts to the wetland due to Grand Ditch construction, Lulu City development, mining, and beaver extirpation are therefore unknown. In order to understand pre-impact processes, a ground penetrating radar (GPR) survey, trenching, coring, and radiocarbon dating were used to map sediment deposits, assess aggradational rates, and quantify processes (channel, overbank, hillslope, beaver dams, peat) of alluvial fill within the Upper Colorado River valley. Results suggest 1) recent ditch-initiated debris flows have increased the rate of aggradation in the wetland by approximately four times, 2) several pre-impact debris flows identified in the past 4000 years show similar textures to surface deposits, 3) delineation of the 2003 sediment deposit in the Lulu City wetland is possible, and 4) radiocarbon dates suggest peat accumulation ceased on the west side of the wetland concurrently with the impacts of the 19th and 20th century. These understandings of historic processes can provide function-based goals for restoration.

fluvial processes, river restoration, aggradation rates, sediment transport

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Brian Sanford
Colorado State University
bsanford@lamar.colostate.edu

Implications of Hydrothermal Alteration for Landscape Stability and Environmental Geochemistry

The bedrock of the Never Summer Mountains of Rocky Mountain National Park contains areas that have undergone hydrothermal alteration. The extent and geochemistry of this alteration is unknown and, as a result, its environmental implications are also unknown. Rocks that have undergone hydrothermal alteration display specific characteristics, of which a change in mineralogy is most identifiable. Altered rocks may also display a decrease in strength properties,

as well as sulfide mineralization. The mineralogical changes that take place during alteration are dependent on the degree and nature of hydrothermal activity. Hydrothermal alteration, in many cases, produces clay minerals. The presence of these minerals often indicates a decrease in the strength properties of the rock. This weakening of the rock by alteration may lead to slope failure. Slope failures in areas of hydrothermal alteration may expose large areas of sulfide minerals. Weathering and oxidation of sulfide minerals at the surface leads to acid generation and is commonly referred to as acid rock drainage (ARD). Several factors influence the degree of acid generation. These include the extent of hydrothermal alteration that produced the sulfide minerals, level of exposure of sulfide minerals to the atmosphere, and weathering rates of the altered rock. The rate of acid generation is dependent on the level of exposure of these minerals to the surface environment. This project has two main objectives: to determine the area and degree of hydrothermal alteration and to assess current and potential environmental impacts of this alteration. Seventeen water samples were collected. The samples were taken along various creeks above and below the ditch. Eighteen rock samples collected were chosen for thin section. The areas of primary interest are along the Grand Ditch and include Red Mountain, Little Yellowstone, and the site of the ditch breach in 2003.

geochemistry, alteration, sulfide, acid rock drainage (ARD), Never Summer Mountains

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Rick Scherer
Colorado State University
scherer@cnr.colostate.edu

Erin Muths
U.S. Geological Survey

Barry Noon
Colorado State University

Sara Oyler-McCance
U.S. Geological Survey

Status and Spatial Distribution of Amphibians in the Kawuneeche Valley

The Kawuneeche Valley is the only location in Rocky Mountain National Park with historic observations of all four extant amphibian species: wood frogs, boreal chorus frogs, boreal toads, and tiger salamanders. I conducted surveys in the Kawuneeche Valley and estimated the proportion of wetlands that were occupied by each species from 2004 to 2006. I also evaluated hypothesized relationships between occupancy and several environmental variables. Observations of boreal toads and tiger salamanders were rare. Breeding wood frogs, however, occupied approximately 12% of the wetlands across the three years of the study, while occupancy by boreal chorus frogs increased from approximately 20% in 2004 to 37% in 2006. Occupancy by wood frogs was positively associated with the amount of streamside habitat adjacent to a wetland and negatively associated with the cost-based distance to the nearest occupied wetland. Occupancy by boreal chorus frogs was positively associated with the number of neighboring, occupied wetlands. In a related study, I used eight microsatellite markers to assess the genetic population structure and estimate levels of genetic variability in the population of wood frogs in the Kawuneeche Valley. The results from this analysis indicate the population is partitioned into two genetic clusters, and each cluster has relatively low levels of genetic variability.

amphibian, wood frog, boreal chorus frog, occupancy, Kawuneeche Valley, wetland

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Rick Scherer
Colorado State University
scherer@cnr.colostate.edu

John Shepherd
Rocky Mountain National Park

Becky Ditgen
Rocky Mountain National Park

Barry Noon
Colorado State University

Ian Leinwand
Colorado State University

Status of Beaver in Rocky Mountain National Park

Beaver (*Castor canadensis*) are known to have profound impacts on landscapes and alter the structure and function of ecosystems. After decades of persistent trapping and habitat loss, the beaver population in North America was nearly extirpated. In Rocky Mountain National Park, historic data indicate that a decline in the abundance of beaver began as recently as the 1940s. Though populations of beaver are recovering in many areas across its historic range, the beaver population in the park remains small. We used park staff and volunteers to conduct surveys for beaver and collect measurements of environmental attributes at 58 plots across the park. Evidence of current beaver presence was detected in seven plots (12%), while evidence of historic beaver presence was detected in 42 plots (72%). Of the seven plots with signs of current beaver presence, six plots were in areas predicted to have highly suitable habitat by a recent habitat modeling project. We will discuss additional results from this study, as well as the implications of these results for future beaver surveys.

beaver, Castor canadensis, occupancy, citizen science

Kate Schoenecker (presenter)
U.S. Geological Survey
Colorado State University
kate_schoenecker@usgs.gov

Bruce Lubow
Colorado State University

Therese Johnson
Rocky Mountain National Park

Developing a More Accurate Population Survey Method for Elk in Rocky Mountain National Park

The Elk and Vegetation Management Plan for Rocky Mountain National Park seeks to restore the natural range of variation to a regional elk population and vegetation conditions to support high biodiversity and wildlife viewing opportunities. The plan uses a combination of management actions including culling, aversive conditioning, and fencing to reduce elk numbers and densities and to restore plant communities. Adaptive implemetation of the management plan requires monitoring changes in vegetation conditions and elk population size to determine progress toward meeting objectives set in the plan. The controversial nature of some of the actions makes it especially critical that management decisions be based on reliable science. Timely, accurate, and comprehensive population monitoring data—despite the challenges posed by the park's high altitude, difficult terrain, and unobstructed boundary (permitting frequent elk movements in and out of the park)—is essential to success of the plan.

Current methods for surveying elk apply a fixed sightability correction model developed >15 years ago to adjust raw counts for missed elk. Our project seeks to develop and validate an improved method that uses a form of mark-resighting survey with paired independent aerial observers. This method incorporates covariates such as group size, vegetation, and snow cover like the sightability correction model. Unlike the sightability model, however, our method can also incorporate differences in observer abilities and changes in sighting conditions over time. The new method also continues to accumulate an ever increasing sample size for more precise correction model estimates. The availability of elk marked with radio collars for another ongoing study is serving as a valuable source of data for validation of the new method. The goals of this project are to enhance and update the methods used to survey elk within the park, gain a more comprehensive understanding of elk use throughout the critical winter period and the natural variation in elk use as a function of population size and weather, and, finally, to consider the impact on visitors as we try to maintain rigorous, reliable data collection standards. Project progress and preliminary results will be presented.

population dynamics, elk

Anna W. Schoettle
USDA Forest Service
aschoettle@fs.fed.us

Betsy Goodrich
Mountain Studies Institute
USDA Forest Service

Jen Klutsch
Mountain Studies Institute
USDA Forest Service

Kelly S. Burns
USDA Forest Service

Sheryl Costello
USDA Forest Service

Richard A. Sniezko
USDA Forest Service

Jeff Connor
Rocky Mountain National Park

Conserving Genetic Diversity of Limber Pine in Rocky Mountain National Park

Limber pine (*Pinus flexilis*) has a patchy distribution spanning a broad latitudinal and elevation range in western North America. In northern Colorado, limber pine grows from below lower treeline up to alpine treeline - from 1600 m in the short grass steppe to over 3300 m elevation near the continental divide. It covers approximately 2700 acres in Rocky Mountain National Park and is common along Trail Ridge Road and many of the east-side hiking trails. These trees provide many ecosystem services including food for corvids, bears and squirrels, watershed protection and picturesque gnarled tree forms on exposed sites. This species is currently being impacted by mountain pine beetle (MPB, *Dendroctonus ponderosae*) and is threatened by the spread of *Cronartium ribicola*, a non-native fungal pathogen that caused the lethal disease white pine blister rust (WPBR). Symptoms of the disease were found on limber pine in the park in 2009. In 2008, we initiated a program to conserve limber pine genetic diversity for possible future restoration in the park. This is a multifaceted program that focuses on 17 stands of limber pine on the east side of the park. The goals are to (1) provide in situ protection of 15 limber pine in each stand from MPB attack to preserve the seed sources, (2) provide ex situ conservation of genetic diversity of the limber pine populations, (3) estimate the geographic variation in the frequency of resistance to WPBR among the populations, (4) identify seed trees with heritable resistance to WPBR, and (5) characterize stand structure and regeneration in these limber pine stands. This presentation will summarize our progress and discuss how this research program will provide information to assist managers to evaluate potential management options to sustain limber pine in the park in the future.

Pinus flexilis, limber pine, white pine blister rust, mountain pine beetle, gene conservation, disease resistance, regeneration, proactive intervention

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E. William Schweiger
National Park Service Rocky Mountain Inventory and Monitoring Network
Billy_Schweiger@nps.gov

Katie Driver
Colorado State University

David Cooper
Colorado State University

Isabel Ashton
National Park Service Rocky Mountain Inventory and Monitoring Network

Donna Shorrock
National Park Service Rocky Mountain Inventory and Monitoring Network

The Vitals of Wetland: Bioassessment of Park-Scale Wetland Ecological Integrity in Rocky Mountain National Park

Wetland in Rocky Mountain National Park is threatened by hydrologic and floristic modification due to elk and (lack of) beaver, invasive flora and climate change. We will present preliminary results and findings from a three year pilot project that has developed a rigorous survey design and bioassessment approach to the long-term monitoring of wetland. Data collected at over 125 sites to date include quantitative vegetation assemblage composition and cover, ground water hydrology, vegetation herbivory and semi-qualitative measures of several environmental attributes. We are developing integrative assessment models including a multimetric Index of Biotic Integrity and a multivariate Observed:Expected model that will predict assemblage composition based on a suite of geophysical attributes that structure wetland condition. These models will allow informed and management relevant assessment of wetland integrity. We will present initial results from these efforts and discuss the connection between vital signs monitoring, reference conditions and the desired future condition of wetland in the park.

wetland, bioassessment, ecological integrity, monitoring

Richard W. Scully
Lyons, Colorado
richwscully@msn.com

Mary Jane Howell
Lyons, Colorado

Inventory of *Potentilla rupincola* in Rocky Mountain National Park

An inventory of the rare endemic plant *Potentilla rupincola* has been performed in Rocky Mountain National Park. *P. rupincola* is known only from Colorado. The park is one of the main centers of *P. rupincola* occurrences, and it is the location where the plant reaches its highest altitude, which lies a short ways below timberline (10,850 feet elevation).

Prior to 1994 only two collections of *P. rupincola* from the park were known, and these were made in the 1930s and gave only vague location or habitat information. The rediscovery of one population by the investigators in 1994 led to the recognition of a subalpine search image for the plant. In the park, the plant occurs mostly in Limber pine ecosystems. Previously the plant had been known mainly from montane and foothills habitats with Ponderosa pine.

Five sub-populations of *P. rupincola* that are true to type have been mapped in the park. The park contains roughly 6,000 plants, which constitutes about one-sixth of the worldwide total, so far as is known. The study documented two locations where trails bisect populations, which the park now manages with log barriers. A considerable amount of potentially suitable habitat in the park remains to be searched.

Over most of its range, *P. rupincola* intergrades with the closely related species *Potentilla effusa*. Apparent intermediates between *P. rupincola* and *P. effusa* occur in montane habitat on the eastern boundary of the park. Opinions vary as to which species these belong to.

Potentilla ovina, an alpine to subalpine plant with an overlapping range, is sometimes mistaken for *P. rupincola*. Several voucher specimens of *P. rupincola* and other, look-alike Potentilla species were collected and deposited at the University of Colorado Herbarium, with duplicates to the park herbarium.

Potentilla, Potentilla rupincola, species inventory, endemic plant, rare plant

Ted R. Sedell (presenter)
Montana State University
tsedell@gmail.com

Robert E. Gresswell
U.S. Geological Survey

Predicting the Responses of Native Trout to Post-Wildfire Debris Flows in Headwater Streams

Native trout populations in western North America have declined over the last century due to habitat fragmentation and degradation, and invasive species. With projected impacts from climate change including increased temperatures, an altered hydrograph, and increased risk of catastrophic fire, long-term persistence of native trout populations is uncertain, particularly in

vulnerable headwater streams. Populations in headwater streams may be especially susceptible to catastrophic disturbances in the form of debris flow torrents, for the risk of catastrophic debris flows increases exponentially in landscapes that have experienced recent wildfires. Accordingly, management for the long-term persistence of native trout will require identifying debris flow-prone areas across the landscape. Predicting the timing, extent, and severity of future wildfires or subsequent precipitation and runoff events is difficult; however it is possible to identify channels within stream networks that may be prone to debris flows with currently available debris flow risk models. The main objective of this study is to assess debris flow potential in high elevation streams of the Colorado Rocky Mountains using fine-scale spatial analysis. We identified at-risk channels using models based on characteristic storm and burn scenarios and geographic information describing topographic, soil, and vegetation characteristics. These channels were mapped in 12 stream networks within the headwaters of the Colorado River containing native trout to provide information about the potential for catastrophic population disturbance from combinations of wildfire and debris flow risk, two of which were located in Rocky Mountain National Park. To date, application of GIS models suggest that populations in many of these watersheds occupy areas with a high probability of post-wildfire debris flows, but the wide spatial extent of their distribution may reduce risk of extirpation. Ultimately, the combination of population, wildfire, and debris flow risk data can be used to develop more comprehensive management strategies for restoration, protection, and post-disturbance remediation of native fishes.

native trout, wildfire, debris flow, landscape, GIS

Jason Sibold
Colorado State University
Jason.sibold@colostate.edu

Disturbance and Management History Influences on Mountain Pine Beetle Outbreak Severity and Post-Outbreak Stand Development, Rocky Mountain National Park

Rocky Mountain National Park is currently experiencing a mountain pine beetle (MPB; *Dendroctonus ponderosae*) outbreak of unprecedented scale and severity that will reshape the lodgepole pine forest landscape of the Park for decades to centuries in the future. Understanding patterns of outbreak severity and post-outbreak stand development will help elucidate the ecological consequences of the outbreak for the lodgepole pine forest type. Based on evidence from past bark beetle outbreaks it is clear that patterns of MPB outbreak severity and post-outbreak forest development are strongly related to the characteristics of individual stands, which in turn are associated with stand disturbance and management history. The goal of this research was to quantify how disturbance and management histories influence outbreak severity and post-outbreak stand development trajectories. To address these research questions I measured severity (percent mortality) and establishment at paired stands with different disturbance or management histories on the west side of the park. Outbreak severity and stand-development trajectories were not influenced by differences in stand-replacing fire history (stand age), or the occurrence of past surface fires. In contrast, severity and development trajectories were influenced by the occurrence of the 1970s MPB outbreak and ecosystem management treatments including tree thinning with and without subsequent burning of slash piles and high-severity prescribed fire.

mountain pine beetle, disturbance interactions, stand development, ecosystem management

Byron M. Straw
University of Northern Colorado
Byron.Straw@unco.edu

Kenneth D. Hopkins
University of Northern Colorado

Assessment of Latest Glacial and Postglacial Deposits in Lake of the Clouds Cirque, Never Summer Mountains, Colorado

Glacial and periglacial deposits in the Never Summer Mountains on the western boundary of Rocky Mountain National Park are exceptionally well preserved and provide a record of late-glacial and postglacial climate changes that affected the park. The relatively low-gradient valley-floor profiles of eastward draining tributaries of the Colorado River favored deposition and preservation of moraines as glaciers retreated into cirques at the close of the Pinedale Glaciation.

In the Lake of the Clouds cirque, three closely spaced terminal moraines are located on the valley floor approximately 1.5 km from the cirque headwall. The lower and middle moraines enclose small fens on their upstream sides, while the uppermost moraine is partly overlapped by a large

compound tongue-shaped rock glacier. Several smaller lobate rock glaciers and protalus ramparts are located around the perimeter of the cirque.

Soils on the three moraines have an A/Bw/Cox profile similar to Satanta Peak soil profiles found in the adjacent Front Range. A radiocarbon date of 11,595 14C yr BP obtained from basal sediment in a core taken from the fen behind the middle moraine provides a close minimum age for the moraine and suggests that deposition of the moraine may have been coeval with the European Younger Dryas event. A 23-cm-thick peat layer in the midsection of the same core yielded a radiocarbon date of 6200 14C yr BP, and reflects a period of warmer climate and a rise of treeline during the Altithermal interval. Rock-weathering and lichenometric data collected at 11 stations on the periglacial deposits record three episodes of periglacial activity in post-Altithermal time. The lower lobe of the large tongue-shaped rock glacier, however, is clearly pre-Altithermal in age. It is likely to be of glacigenic origin and probably formed as ice downwasted during retreat from the upper moraine.

glacial, periglacial, Never Summer Mountains, Younger Dryas, rock glacier, Colorado

Kathy Tonnessen
National Park Service Rocky Mountains Cooperative Ecosystem Studies Unit
kathy_tonnessen@nps.gov

Pei-Lin Yu
National Park Service Rocky Mountains Cooperative Ecosystem Studies Unit
pei-lin.yu@cfc.umt.edu

Ten Years in Ten Minutes, a Short History of the Rocky Mountains Cooperative Ecosystem Studies Unit in Cooperation with Rocky Mountain National Park

Since the launch of the Rocky Mountain Cooperative Ecosystem Studies Unit (RM-CESU) in 1999, Rocky Mountain National Park, has seen increases in visitor use, invasive species, insect outbreaks, air and water pollution and attempted large scale ecosystem restoration and vegetation manipulation. Effects of climate change on ecosystems, cultural resources and facilities are looming on the horizon, and the park has a need to work with agency partners and cooperating universities to get the research and technical assistance that managers need to deal with these threats. We will provide a short history of the RM-CESU and provide a few examples and themes that have been pursued by our partners at Rocky Mountain National Park. We will offer insights into future use of this flexible and efficient agreement to allow managers to get research and technical assistance in the areas of planning, social science, natural and cultural resource management and restoration.

cooperative ecosystem studies unit, cooperative agreement

Mary Kay Watry (presenter)
Rocky Mountain National Park
mary_kay_watry@nps.gov

Kate Schoenecker
U.S. Geological Survey
Colorado State University

Gordon Luikart
Montana State University

Laura Ellison
U.S. Geological Survey

Developing a Non-Invasive Technique to Estimate Population Size of Bighorn Sheep in Rocky Mountain National Park using Fecal-DNA

Developing non-invasive techniques to study large mammals is the goal of many wildlife managers and researchers. Handling ungulates causes stress to animals and risk to humans. In certain places, such as Rocky Mountain National Park, flying helicopters to radio tag or mark ungulates in wilderness is heavily scrutinized. The development of viable alternatives is needed. Based on research and modeling by McClintock (2006), the bighorn sheep population on the east side of the park (Mummy Range) is predicted to become extirpated by 2020 if the rates of decline observed during the study continue. It is unclear whether these declines have continued between McClintock's last field season in 2004 and the present time. Thus bighorn sheep population monitoring in the park is a high priority, and population and density estimates are essential for successful management and conservation of the species. We are conducting a study to develop a non-invasive population estimation technique using fecal DNA. Mark re-capture models will be used to estimate parameters such as population size and survival, where the "mark" will be an individual animal's DNA. If this technique is viable and less costly (and less risky) than traditional aerial helicopter monitoring, park managers may be able to determine trends in bighorn sheep and other wildlife populations, which would inform a variety of management decisions. We are beginning the second year of this two-year study. Current project progress will be discussed.

bighorn, population dynamics, mark-recapture

Nate Williamson
Rocky Mountain National Park
nwilliamson@nps.gov

Mike Lewelling
Rocky Mountain National Park

Monique Rocca
Colorado State University

Bill Romme
Colorado State University

Impacts of Mountain Pine Beetle on Lodgepole Pine Fire Behavior in Rocky Mountain National Park

Mountain pine beetle (*Dendroctonus ponderosae*) populations have reached epidemic levels throughout the western United States and Canada. Although the pine beetle is a native insect, population levels currently being observed are without precedent in recorded history. The resultant tree mortality will affect future stand structure and composition and fuel dynamics in our forests for decades to come. There is considerable uncertainty as to how the current epidemic will affect future fire behavior in beetle-killed stands.

Following attack by the beetle, the impacted trees are killed and the needles subsequently die and dry out. These red needles will remain on the tree for two to three years before falling to the forest floor. It is thought that the risk of a crown fire may be greater in stands composed primarily of standing dead trees with red needles than in stands of green trees. A prescribed burn project was conducted at Rocky Mountain National Park to investigate the flammability of lodgepole pine crowns as well as the mechanisms of pine seed dispersal following beetle attack.

mountain pine beetle, lodgepole pine, fire behavior, crown fire

Don Zimmerman
Colorado State University
don.zimmerman@colostate.edu

Teresa Yohon
Colorado State University

Mike Whatley
National Park Service Natural Resource Program Center

Sara Melena
National Park Service Natural Resource Program Center

Jeff Goehring
National Park Service Natural Resource Program Center

Enhancing the National Park Service Natural Resource Program Center Intranet Website

The National Park Service (NPS) Natural Resource Program Center (NRPC), Fort Collins, asked researchers at Colorado State University's Center for Research on Communication and Technology to conduct a research project to help the NRPC enhance its intranet website. We used three methodologies: card sorting, usability testing of pilot prototype of a new NRPC website, and heuristic review.

The objective of the card sorting was to learn how National Park Service and Rocky Mountain National Park staff would organize information for the website and to identify terms they would use for the website links. The usability testing focused on identifying the strengths of the prototype website design, identifying features that created problems for users, and assessing participants' perception of the website. The heuristic review provided recommendations to the NRPC staff based on the emerging body of empirical research on website design.

Thirty three NPS staff (24 from the NRPC and nine from the park) participated in the card sorting; 18 NPS staff (12 from the NRPC and six from the park) assisted with the usability testing.

The card sorting provided a revised organization and links for the prototype website. The usability testing provided eight guidelines for revising the prototype website: (1) The organization of the NRPC's work groups was not intuitive, (2) Content areas were hard for some users to identify, (3) The website prototype used an inconsistent navigation design, (4) Participants missed links on the right-hand side of the pages, (5) Returning to the home page presented a problem for some users, (6) Participants missed the breadcrumbs (navigational links), (7) The font size is hard to read and too small for some participants, (8) Some participants had problems understanding the icons. We provided seven additional recommendations based on our heuristic review.

Natural Resources Program Center intranet, usability testing, card sorting, NPS Office of Education and Outreach, NPS Natural Resource Program Center

Authors and Presenters

S.R. Abt
Engineering Research Center
Colorado State University

Paul Ackerman
Colorado State University

Ruth M. Alexander
Professor
Department of History
Colorado State University
Ruth.Alexander@ColoState.EDU

Carissa F. Aoki
Department of Forest, Rangeland, and Watershed Stewardship
Colorado State University
caoki@warnercnr.colostate.edu

Isabel Ashton
Ecologist
National Park Service
Rocky Mountain Inventory and Monitoring Network
Fort Collins, CO
Isabel_ashton@nps.gov

Keith Attenborough
Department of Engineering
University of Hull
Kingston Upon Hull, UK

William L. Baker
University of Wyoming

Ben Baldwin
Research & Learning Specialist
Continental Divide Research Learning Center
Rocky Mountain National Park
ben_baldwin@nps.gov

Rose Banks
University of Wyoming
ebanks@uwyo.edu

Jill Baron
U.S. Geological Survey
Colorado State University
jill@nrel.colostate.edu

Benjamin Barst
Department of Biological Sciences and Institute of Applied Science
University of North Texas
Denton, TX
benbarst@hotmail.com

Katherine Beem
Colorado State University

James B. Benedict
Center for Mountain Archeology
no email address

Leanne Benton
Rocky Mountain National Park
leanne_benton@nps.gov

William D. Bowman
Department of Ecology and Evolutionary Biology and
Institute of Arctic and Alpine Research
University of Colorado, Boulder
william.bowman@colorado.edu

Richard Bray
Rocky Mountain National Park
mtlep@earthlink.net

Jenny Briggs
Rocky Mountain Geographic Science Center
U.S. Geological Survey
Denver, CO
jsbriggs@usgs.gov

Robert H. Brunswig
Department of Anthropology
University of Northern Colorado
rhbruns@unco.edu

Kristin Bunte
Engineering Research Center
Colorado State University
kbunte@engr.colostate.edu

Kelly S. Burns
USDA Forest Service
Forest Health Management
Lakewood, CO

Christian M. Carrico
Colorado State University
carrico@lamar.colostate.edu

Slavomir Celer
Administration of Tatra National Park
State Nature Conservancy
Tatranska Strba
celer@sopsr.sk

Robert Chamberlin
PE/PTOE
Resource Systems Group Inc.
White River Junction, VT
rchamberlin@rsginc.com

C. M. Cleaver
Department of Bioagricultural Sciences and Pest Management
Colorado State University

David Clow
U.S. Geological Survey
dwclow@usgs.gov

Jeffrey L. Collett
Colorado State University

Jeffrey Connor
Rocky Mountain National Park

David Cooper
Professor/Senior Research Scientist
Department of Forestry, Range, and Watershed Stewardship and
Graduate Degree Program in Ecology
Colorado State University
davidc@warnercnr.colostate.edu

Leigh A. Cooper
CIRES Center for Limnology
University of Colorado

Sheryl Costello
USDA Forest Service
Forest Health Management
Denver, CO
scostello@fed.fs.us

Ashley D'Antonio
MS Candidate
Department of Environment and Society
Utah State University
ashleydantonio@gmail.com

Derek Day
Colorado State University

Thomas M. Detmer
CIRES Center for Limnology
University of Colorado

Patricia Dienstfrei
Metropolitan State College of Denver

David Diggs
Department of Geography
University of Northern Colorado
Greeley, Colorado

Matthew Diskin
Department of Forest, Rangeland, and Watershed Stewardship
Colorado State University
mattdiskin@gmail.com

Becky Ditgen
Rocky Mountain National Park

James Doerner
Department of Geography
University of Northern Colorado
Greeley, Colorado

Katie Driver
Graduate Degree Program in Ecology
Colorado State University
kmdriver@warnercnr.colostate.edu

Sarah Eaton
Rocky Mountain National Park
kountess@bellsouth.net

Karin Edwards
Rocky Mountain National Park

Laura Ellison
U.S. Geological Survey

Fred C. Engelman
Rocky Mountain National Park
fcengelman@earthlink.net

Tena Engelman
Rocky Mountain National Park

Liesl Peterson Erb
Department of Ecology and Evolutionary Biology
University of Colorado at Boulder
liesl.peterson@colorado.edu

Vera Evenson
Denver Botanic Gardens

Jennifer A. Fike
U.S. Geological Survey
Fort Collins Science Center and
Rocky Mountain Center for Conservation Genetics and Systematics
Department of Biological Sciences
University of Denver

Peter Fleischer
Research Station and Museum of Tatra National Park
State forest of TANAP
Ttaranska Lomnica
059 60 Vysoke Tatry
Slovakia pfleischer@lesytanap.sk

Larry Gamble
Chief of Planning and Compliance
Rocky Mountain National Park
larry_gamble@nps.gov

Adam Gibson
PhD Candidate
Human Dimensions of Natural Resources Department
Colorado State University
adamgibson00@gmail.com

Jeff Goehring
Graphic Web Designer
National Park Service Office of Education and Outreach
Natural Resource Program Center
Fort Collins, CO

Betsy Goodrich
Department of Bioagricultural Sciences and Pest Management
Colorado State University and
Mountain Studies Institute
Silverton, CO and
USDA Forest Service
Rocky Mountain Research Station
Fort Collins, CO
betsy.goodrich@colostate.edu

Mark Graham
New River Gorge National River

Karey Grant
Metropolitan State College of Denver

Robert E. Gresswell
U.S. Geological Survey Northern Rocky Mountain Science Center
Bozeman, MT
bgresswell@usgs.gov

Robert Guralnick
Department of Ecology and Evolutionary Biology and
Museum of Natural History
University of Colorado

Robert M Hallock
University of Colorado, Denver
rob.hallock@ucdenver.edu

Rich Hansen
U.S. Department. of Agriculture
USDA-APHIS-PPQ-CPHST
Fort Collis, CO
richard.w.hansen@aphis.usda.gov

J. A. Hardin
Department of Bioagricultural Sciences and Pest Management
Colorado State University

Jared Heath
Colorado State University

Karen Hockett
Assistant Professor
Department of Forestry
Virginia Polytechnic University
Blacksburg, VA,

Kenneth D. Hopkins
University of Northern Colorado

Mary Jane Howell
Lyons, Colorado

Karista Hudelson
Department of Biological Sciences and Institute of Applied Science
University of North Texas
Denton, TX

William Jacobi
Professor
Department of Bioagricultural Science and Pest Management and
Graduate Degree Program in Ecology
Colorado State University
william.jacobi@colostate.edu

Jason Janke
Department of Earth and Atmospheric Sciences
Metropolitan State College of Denver
Jjanke1@mscd.edu

Kenneth K Jensen
School of Medicine
Indiana University
Bloomington, IN

Amanda Jeter
College of Architecture and Planning
Landscape Architecture Program
University of Colorado, Denver
mandajet@gmail.com

Therese Johnson
Rocky Mountain National Park
therese_johnson@nps.gov

Kristen M. Kaczynski
PhD student
Graduate Degree Program in Ecology
Colorado State University
kristen.kaczynski@colostate.edu

Ken Kaliski
Resource Systems Group Inc.
White River Junction, VT
kkaliski@rsginc.com

Stephanie Kampf
Colorado State University
skampf@warnercnr.colostate.edu

Jan Kilgore
Rocky Mountain National Park

Jen Klutsch
Mountain Studies Institute
Silverton, CO and
USDA Forest Service
Rocky Mountain Research Station
Fort Collins, CO

Cori Knudten
Colorado State University
coriknudten@yahoo.com

Matthew J. Kovach
Department of Biological Sciences and
Institute of Applied Science
University of North Texas
Denton, TX

Natalie Kramer
MS Candidate
Geosciences
Colorado State University
nkramer@lamar.colostate.edu

Sonia M. Kreidenweis
Colorado State University

Michael Kuo
Eastern Illinois University

Ole N. Larsen
Department of Biology
University of Southern Denmark
Odense, DK

Steve Lawson
Director, Public Lands Planning and
Management
Resource Systems Group Inc.
White River Junction, VT
srlawson@rsginc.com

Matt Layden
National Atmospheric Deposition Program

Ian Leinwand
Colorado State University

Ezra Levin
Colorado State University

Mike Lewelling
Rocky Mountain National Park
mike_lewelling@nps.gov

Bruce Lubow
Colorado State University

Gordon Luikart
Montana State University

Sean P. Maher
Department of Ecology
and Evolutionary Biology and
Biodiversity Institute
University of Kansas
maher@ku.edu

William Malm
National Park Service

Julie Markus
The Ohio State University

James H. McCutchan, Jr.
CIRES Center for Limnology
University of Colorado
james.mccutchan@colorado.edu

Sara Melena
Interpretive Specialist
National Park Service Office
of Education and Outreach
Natural Resource Program Center
Fort Collins, CO

Kristen Meyer
USDA Forest Service
Rocky Mountain Research Station
Fort Collins, CO and
Mountain Studies Institute
Silverton, CO
kemeyer@fs.fed.us

Mike Miller
Colorado Division of Wildlife

Chris Monz
Assistant Professor
Recreation Ecology and Management
Department of Environment and Society
The Ecology Center
Utah State University
chris.monz@usu.edu

Erin Muths
U.S. Geological Survey
erin_muths@usgs.gov

Jose Negron
Rocky Mountain Research Station
USDA Forest Service
Fort Collins, CO

Kellen N. Nelson
Department of Forest, Rangeland,
and Watershed Stewardship
Colorado State University
knelson@warnercnr.colostate.edu

Peter Newman
Associate professor
Human Dimensions of Natural
Resources Department
Colorado State University
Peter.Newman@colostate.edu

Barry Noon
Colorado State University

Brooke B. Osborne
Colorado State University
bosborne@nrel.colostate.edu

Sara Oyler-McCance
U.S. Geological Survey
Fort Collins Science Center and
Rocky Mountain Center for Conservation
Genetics and Systematics
Department of Biological Sciences
University of Denver
sara_oyler-mccance@usgs.gov

Logan Park
Assistant Professor
Department of Forestry
Southern Illinois University
Carbondale, IL
logan.park@siu.edu

Townsend Peterson
Department of Ecology
and Evolutionary Biology and
Biodiversity Institute
University of Kansas

David Pettebone
Social Science Specialist
Visitor Use and Social Sciences Resources
Management and Science Division
Yosemite National Park
David_Pettebone@nps.gov

Covey Potter
Colorado State University
coveyp@gmail.com

John P. Potyondy
USDA Forest Service
Stream Systems Technology Center

Jenny Powers
National Park Service
Biological Resources Management Division
Jenny_Powers@nps.gov

Sara L. Rathburn
Associate Professor
Department of Geosciences
Colorado State University
rathburn@cnr.colostate.edu

John Ray
National Park Service
Air Resources Division
John_D_Ray@nps.gov

Chris Ray
Department of Ecology
and Evolutionary Biology
University of Colorado Boulder

Eric Richer
Natural Resource Ecology Laboratory
Colorado State University
eericher@nrel.colostate.edu

Tobias Riede
National Center for Voice and Speech
Department of Biology
University of Utah
Salt Lake City, UT
t.riede@utah.edu

Aaron P. Roberts
University of North Texas
Department of Biological Sciences and
Institute of Applied Science
Denton, TX
Aaron.Roberts@unt.edu

Monique E. Rocca
Department of Forest, Rangeland,
and Watershed Stewardship
Colorado State University

William H. Romme
Department of Forest, Rangeland,
and Watershed Stewardship
Colorado State University

Zan K. Rubin
Department of Geosciences
Colorado State University
zan@lamar.colostate.edu

Brian Sanford
Colorado State University
bsanford@lamar.colostate.edu

Rick Scherer
Colorado State University
scherer@cnr.colostate.edu

Bret Schichtel
National Park Service

Kate Schoenecker
U.S. Geological Survey and
Colorado State University
kate_schoenecker@usgs.gov

Anna W. Schoettle
USDA Forest Service
Rocky Mountain Research Station
Fort Collins, CO
aschoettle@fs.fed.us

Tony Schountz
School of Biological Sciences
University of Northern Colorado

Richard W. Scully
Lyons, Colorado
richwscully@msn.com

Misha Schurman
Colorado State University

E. William Schweiger
Ecologist
National Park Service
Rocky Mountain Inventory and Monitoring
Network
Fort Collins, CO
Billy_Schweiger@nps.gov

Ted R. Sedell
Montana State University
Bozeman, Montana
tsedell@gmail.com

John Shepherd
Rocky Mountain National Park

Donna Shorrock
Ecologist
National Park Service
Rocky Mountain Inventory and Monitoring
Network
Fort Collins, CO
Donna_Shorrock@nps.gov

Jason S. Sibold
Assistant Professor of Geography
Department of Anthropology
Colorado State University
Jason.sibold@colostate.edu

James D. Smith
Department of Biological Sciences and
Institute of Applied Science University of
North Texas
Denton, TX

Richard A. Sniezko
USDA Forest Service,
Dorena Genetic Resources Center
Cottage Grove, OR

Terry Spraker
Colorado State University

Sky Stephens
Colorado State Forest Service
Fort Collins, CO

Byron M. Straw
University of Northern Colorado
Byron.Straw@unco.edu
Ben Swanson
Resource Systems Group Inc.
White River Junction, VT

Kurt W. Swingle
Boulder, CO

Derrick Taff
PhD Student
Human Dimensions of Natural
Resources Department
Colorado State University
derrick.taff@gmail.com

Shahram Taherzadeh
Department of Design, Development,
Environment and Materials
The Open University
Milton, Keynes, UK

Robert M. Timm
Department of Ecology
and Evolutionary Biology and
Biodiversity Institute
University of Kansas

Kathy Tonnessen
National Park Service
Rocky Mountains Cooperative
Ecosystem Studies Unit
University of Montana
Missoula, MT
kathy_tonnessen@nps.gov

Barney J. Venables
Department of Biological Sciences and
Institute of Applied Science
University of North Texas
Denton, TX

Matthew D. Wallenstein
Colorado State University

William T. Waller
Department of Biological Sciences and
Institute of Applied Science
University of North Texas
Denton, TX

Mary Kay Watry
Rocky Mountain National Park
mary_kay_watry@nps.gov

Dan West
Colorado State University

Mike Whatley
National Park Service Office of Education
and Outreach
Natural Resource Program Center
Fort Collins, CO
mike_whatley@nps.gov

Margaret Wild
National Park Service
Biological Resources Management Division

Nate Williamson
Rocky Mountain National Park
nwilliamson@nps.gov

Ellen Wohl
Department of Geosciences
Colorado State University

Teresa Yohon
Center for Research on Communication and
Technology Department of
Journalism and Technical Communication
Colorado State University

Cheri Yost
Rocky Mountain National Park
cheri_yost@nps.gov

Pei-Lin Yu
National Park Service
Rocky Mountains Cooperative
Ecosystem Studies Unit
University of Montana
Missoula, MT
pei-lin.yu@cfc.umt.edu

Don Zimmerman
Center for Research on Communication and
Technology Department of
Journalism and Technical Communication
don.zimmerman@colostate.edu

Your conference hosts:

Ben Bobowski
Chief, Resource Stewardship
Rocky Mountain National Park
ben_bobowski@nps.gov

Judy Visty
Research Administrator
Rocky Mountain National Park
judy_visty@nps.gov

Cheri Yost
Park Ranger
Rocky Mountain National Park
cheri_yost@nps.gov

Jeff Connor
Natural Resource Management Specialist
Rocky Mountain National Park
jeff_connor@nps.gov

Ben Baldwin
Research & Learning Specialist
Rocky Mountain National Park
ben_baldwin@nps.gov

Sarah Eaton
Volunteer
Rocky Mountain National Park

Don Irwin
Park Ranger
Rocky Mountain National Park

Marilyn Irwin
Park Ranger
Rocky Mountain National Park

Don Stewart
Park Ranger
Rocky Mountain National Park

Lois Sumey
Volunteer
Rocky Mountain National Park

Author Index

Abt 14
Ackerman 23
Alexander 10
Aoki 10, 17
Ashton 10, 35
Attenborough 31
Baker 11
Baldwin 11
Banks 11
Baron 12, 23, 27, 30
Barst 12, 32
Beem 15
Benedict 12
Bowman 13
Bray 13
Briggs 16
Brunswig 14
Bunte 14
Burns 34
Celer 19
Chamberlin 15, 27
Cleaver 21
Clow 30
Collett 15
Connor 34
Cooper 22, 24, 28, 35
Costello 16, 34
D'Antonio 16, 25, 27
Day 15
Detmer 24
Dienstfrei 21
Diggs 14
Diskin 10, 17
Ditgen 33
Doerner 14
Driver 35
Eaton 17
Ellison 37
Engelman 18, 28
Erb 18
Evenson 20
Fike 28
Fleischer 19
Gamble 27
Gibson 22, 27
Goehring 38
Goodrich 21, 34
Graham 29
Grant 21
Guralnick 18
Hallock 20
Hansen 20
Hardin 21
Heath 23
Hockett 27
Hopkins 36
Hudelson 12, 32
Jacobi 21, 22
Janke 21
Jensen 31
Jeter 21
Johnson 34
Kaczynski 22
Kaliski 22, 27
Kampf 23
Kilgore 13
Klutsch 16, 34
Knudten 23
Kovach 12, 32
Kramer 23
Kreidenweis 15
Kuo 20
Larsen 31
Lawson 15, 22, 27
Layden 30
Leinwand 33
Levin 15
Lewelling 38
Lubow 34
Luikart 37
Maher 24
Malm 15
Markus 23
McCutchan 24
Melena 38
Meyer 24
Miller 29
Monz 16, 25, 27
Muths 33
Negron 16
Nelson 10, 17
Newman 27, 28
Noon 33
Osborne 27
Oyler-McCance 28, 33
Park 27
Pettebone 27, 28
Potter 28
Potyondy 14
Powers 29
Rathburn 29, 32
Ray, C 18
Ray, J 15, 30
Richer 12, 27, 30
Riede 31
Roberts 12, 32
Rocca 10, 17, 38
Romme 10, 17, 38
Rubin 29, 32
Sanford 32
Scherer 33
Schichtel 15
Schoenecker 34, 37
Schoettle 34
Schountz 24
Schurman 15
Schweiger 35
Shepherd 33
Shorrock 35
Sibold 10, 36
Smith 12, 32
Sniezko 34
Spraker 29
Stephens 16
Swanson 27
Swingle 14
Taff 27
Taherzadeh 31
Timm 24
Titze 31
Tonnessen 37
Venables 32
Wallenstein 27
Waller 32
Watry 37
West 16
Whatley 38
Wild 29
Williamson 38
Wohl 29, 32
Yohon 38
Yost 24
Yu 37
Zimmerman 38