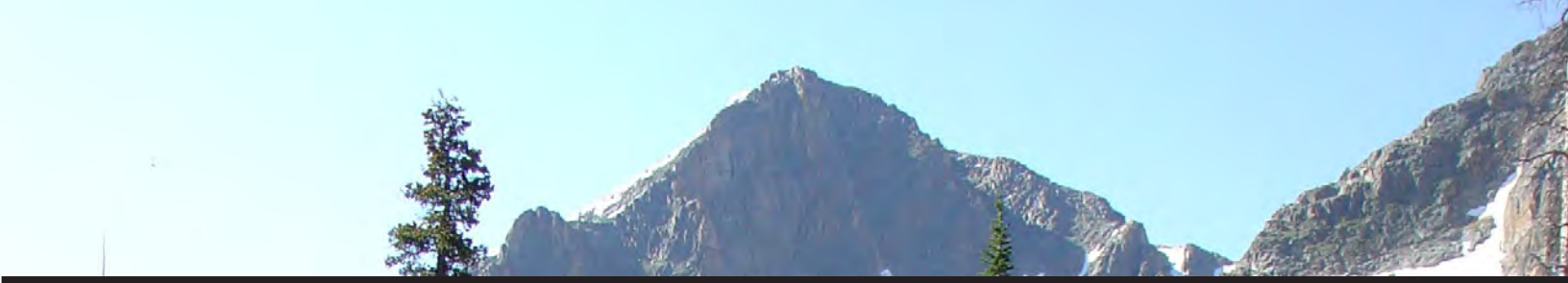

National Park Service
U.S. Department of the Interior

Continental Divide Research Learning Center

Rocky Mountain National Park Research Conference 2012

Photo Credit: Chris Kennedy, U.S. Fish and Wildlife Service

Welcome to Rocky Mountain National Park's 6th Biennial Research Conference!

"For our love of the mountains" is an expression we share with our Sister Parks – the Tatra Mountains of Poland and Slovakia. This expression captures the essence of many of us who feel *called* to the mountains for their solitude, beauty, and protection.

We feel honored to share *our love of the mountains* with so many visitors (more than 3 million in 2011) and in particular to the hundreds of researchers that carry out their work here. Because of the passion and commitment of so many dedicated researchers and their students, Rocky Mountain National Park is better protected through the knowledge gained by more than 100 research investigations, annually.

Thanks to all for their scientific contributions and support – to making Rocky Mountain National Park a special place for this and future generations.

Ben Bobowski, PhD
Chief of Resource Stewardship
Rocky Mountain National Park

reducedwaste INITIATIVE

We are pleased to announce our first research conference to undertake a Reduced Waste Initiative. Join us in making this effort a success by bringing a coffee mug from home and using the recycling and compost bins throughout the buildling. By reducing waste, we uphold the National Park Service's mission to preserve unimpaired natural and cultural resources for the enjoyment, education, and inspiration of this and future generations.

2012 Research Conference Rocky Mountain National Park

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

Wednesday, March 28: Morning Room A: Water, Air, and Soil

8:30-9:00		Coffee and welcome
9:00-9:20		Conference introduction
9:20-9:40	Jill Baron	Empirical Critical Loads of Atmospheric Nitrogen Deposition for Nutrient Enrichment of Mountain Lakes
9:40-10:00	Ellen Wohl	Biotic Drivers of Multi-Thread Channels and the Carbon Cycle
10:00-10:20	Natalie D. Beckman	Log Jams and Carbon Storage in Headwater Streams in Colorado's Front Range.
10:20-10:40		Break
10:40 -11:00	Kyle Grimsley	Debris Flow Chronology and Analysis of Controls on Debris Flow Occurrence in the Upper Colorado River Valley, Rocky Mountain National Park, CO
11:00 -11:20	Katherine B. Benedict	Transport and deposition of reactive nitrogen in Rocky Mountain National Park
11:20 -11:40	Andrew Evans	Macro- and Micronutrient Transport in Frost Affected Soil, Rocky Mountain National Park, Colorado
11:40-12:00	Brooke B. Osborne	Determining Environmental Drivers of Nitrification in Alpine Microbial Ecosystems
12:00-1:00		Lunch

Wednesday, March 28: Afternoon Room A: Vegetation

1:10-1:30	Jenny Briggs	Effects of Mountain Pine Beetle on 3 Species of Pines in Rocky Mountain National Park and the Front Range, 2009-2011
1:30-2:00	David Clow & Leigh Cooper	Responses of Soil and Water Chemistry to Beetle Kill Induced Tree Mortality throughout Colorado and Rocky Mountain National Park
2:00-2:20	Jason Sibold	Rapid Forest Change Stresses Importance of Adaptive Management: A Case Study of Ponderosa Pine in Western Rocky Mountain National Park, CO
2:20-2:40		Break
2:40-3:00	Kristen Kaczynski	Interactions of Native Birds, Ungulates, Fungi, and Drought in the Decline of Riparian Willows
3:00-3:20	Christopher Davis	Effects of Selective Imazapic Application on Bromus tectorum and Non-Target Species in Rocky Mountain National Park
3:20-3:40	Caitlin A. Kelly	Chemical Mediation of Penstemon-Herbivore Interactions: A Comparison Among Colorado Populations

Wednesday, March 28: Afternoon — Room B: Social Science

1:20-1:40	Donald E. Zimmerman	Exploring RMNP Visitors' Information Sources, Communications, and Perceptions of Wildlife Management Practices
1:40-2:00	William J. Gribb	Ecotourism and Sustainable Development: Management Strategies of Rocky Mountain National Park
2:00-2:20	Shawn Davis	Visitor's Concerns about Climate Change in Rocky Mountain National Park
2:20-2:40		Break
2:40-3:00	Donald E. Zimmerman	Assessment of Rocky Mountain National Park Backcountry Campers' Adoption of Leave No Trace Technologies
3:00-3:20	Elliot Dale	Rocky Mountain National Park Waste Audit 2011: Results and Recommendations
3:20-3:40	Derrick Taff	Visitor Perceptions of Alternative Transportation in Yosemite and Rocky Mountain National Parks

2012 Research Conference Rocky Mountain National Park

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

Thursday, March 29: Morning — Room A: Wildlife

8:30-9:00		Coffee
9:00-9:20	Ryan Monello	Prevalence and Effects of Chronic Wasting Disease in Elk from Rocky Mountain National Park
9:20-9:40	Catherine Driscoll	Population Genetic Analysis of Bighorn Sheep (Ovis canadensis) in Rocky Mountain National Park
9:40-10:00	Chris Ray	National Park Service Pika Habitat Occupancy Study: Preliminary Results from Eight Parks
10:00-10:40		Poster Session
10:40 -11:00	Sara J. Oyler-McCance	Investigating Temporal and Spatial Patterns of Genetic Diversity in White-tailed Ptarmigan in and around Rocky Mountain National Park
11:00 -11:20	Greg Wann	Population Demography of White-tailed Ptarmigan at Rocky Mountain National Park
11:20 -11:40	Rich Bray	Long Term Monitoring of Butterflies in Rocky Mountain National Park
11:40-12:00	Fred & Tena Engelman	Rocky Mountain National Park Hummingbird Survey
12:00-1:00		Lunch

Thursday, March 29: Morning — Room B: Mixed Topics

9:00-9:20	Kristin Jacob	The Never Summer Igneous Complex, Rocky Mountain National Park, Colorado
9:20-9:40	Katie Renwick	Will the Mountain Pine Beetle Outbreak Benefit Aspen?
9:40-10:00	Stephanie O'Meara	Flying Through ROMO's Geology – Integrating the NPS Geologic Resources Inventory Geologic Map with Google Earth
10:00-10:40		Poster Session
10:40-11:00	Blaine Hastings	Influence of Digital Elevation Model Resolution on Terrain Based Hydrologic Parameters for a Subalpine Catchment, Front Range, Colorado
11:00-11:20	Curtis Martin	The Colorado Wickiup Project: Ephemeral Native American Wooden Features in Rocky Mountain National Park
12:00-1:00		Lunch

Thursday, March 29 — Room A: International Conservation

1:00-1:20	Ben Bobowski	Introductions
1:20-1:40	Ben Bobowski	A Sister Park Relationship: The Tatra Mountains of Poland and Slovakia and Rocky Mountain National Park, USA
1:40-2:00	James R. Barborak	Using Rocky Mountain National Park as a Living Laboratory for Training Protected Area Managers from around the World
2:00-2:20	David J. Cooper	Comparative Wetland and Alpine Ecosystem Processes in Rocky Mountain National Park and Tatra National Park, Slovakia
2:20-2:40	Jozef Šibík & Ivana Šibíková	Predicting the Responses of Native Trout to Post-Wildfire Debris Flows in Headwater Streams
2:40-3:00		Break
3:00-3:20	Amber Churchill	Review of Research Conducted in Rocky Mountain National Park of CO, USA and the Tatra National Parks of Poland and Slovakia
3:20-3:40	Ben Bobowski	Avian Species Relationships of Rocky Mountain National Park, Colorado, with Monteverde, Costa Rica
3:40-4:00	Christy M. McCain	Mountain Biodiversity Patterns: What Do We Know So Far?
4:00-4:20	Bob Brunswig	Developing Transnational Sister-Park Cultural Resource Research Programs Between Rocky Mountain National Park, the University of Northern Colorado, and the Tatra National Parks of Poland and Slovakia

Thursday, March 29 — Atrium: Poster Session

Jonathan M. Achuff	A Continuing Niche for Ice: Photo-Monitoring of Tyndall and Andrews Glaciers, Rocky Mountain National Park
Nicole Brunner	A Study of the Effectiveness of Rocky Mountain National Park Elk and Vegetation Management Plan on Restoring Riparian Willow in the Core Elk Winter Range
Apryle Craig	The Effects of Willow Condition on Wildlife Diversity
Elliot Dale	Rocky Mountain National Park Waste Audit and Behavioral Change Intervention Initiative
Scott M. Esser	Restoration of the Grand Ditch Breach in the Upper Kawuneeche Valley of Rocky Mountain National Park
Ed Hall	Nitrogen Cycling in Loch Vale Watershed: the Microbial Role in Alpine Biogeochemistry
Jason Janke	Measurement of Soil Nutrient Concentration and Carbon Dioxide Production from Seasonally Frozen Alpine Tundra and Forest Soils
Douglas Klink & Melinda Merrill	Comparing Ozone Data Between Tatra, Estes Park High School, and the Cloudforest in Monteverde
Cara Moore	Relative Sensitivity of the Seasonal Snow Zone to Climate Warming in the Western United States
Joanna Odden	Metagenomic Analysis of Seasonal Bacterial Communities in Alpine Soil of Rocky Mountain National Park
Stephanie O'Meara & Bruce A. Heise	Flying Through ROMO's Geology – Integrating the NPS Geologic Resources Inventory Geologic Map with Google Earth
Noah Purdy & Melinda Merrill	Comparing the Flow of Ozone from Denver, Estes Park High School, to the Longs Peak Ranger Station to the Ute Trail Location
Chuck Rhoades & Byron Collins	Ecosystem Changes after Pine Beetle and Salvage Logging in Colorado Subalpine Forests
Jennifer Sorrentino	Visitor Injury Patterns in Rocky Mountain National Park: 2009 - 2011
Judy Visty	Research Installations in Wilderness

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Poster

A Continuing Niche for Ice: Photo-Monitoring of Tyndall and Andrews Glaciers, Rocky Mountain National Park

Annual monitoring of Andrews and Tyndall glaciers by ROMO personnel from 1934 through 1955 included repeat photography taken from relatively consistent locations at the end of each melt season. The ROMO collection also includes occasional end-of-season photos ranging from 1909 to 1963. Annual photo monitoring resumed in 2000 and is continuing.

These glaciers occupy environmental niches where snowfall, wind, cloudiness, exposure and elevation provide conditions suitable for survival of sufficient ice masses despite notable changes in climate globally. The monitoring photos have captured short-term variations in size, extent and form such as occurred during the drought in 2002 while revealing remarkably little overall change in either glacier over the course of the past century

glacier, monitoring, ice

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Using Rocky Mountain National Park as a Living Laboratory for Training Protected Area Managers from around the World

Ever since the creation of Yellowstone in 1872, the United States has enjoyed global leadership in creation and stewardship of protected natural and cultural areas within the USA, and in contributing to the growth and spread of the protected areas movement globally. Protected areas cover about 14% of the world's land surface and 1% of it seas, and new international agreements aim to dramatically increase the size of the global protected area estate to 17% of the earth's land surface and 10% of its seas within the next few years to counter habitat loss and degradation and the impact of global climate change. To adequately manage existing protected areas and to increase the size of the global protected area system will require a tremendous increase in the number and capacity of conservation agency staff and management institutions at all levels of government and at conservation partners from civil society, academia and the business sector. USNPS and other federal conservation and development agencies play a key role in supporting improved global capacity for protected area management, through technical and financial assistance, exchange visits, sister park agreements, and support for training activities both in the USA and abroad carried out in partnership with non-governmental organizations, the private sector and universities. This presentation highlights longstanding cooperation between Rocky Mountain National Park and Colorado State University in training protected area managers from around the world, using RMNP as a living laboratory to share lessons learned from nearly a century of managerial experience, research and monitoring results, and management of outdoor recreation with protected area managers from around the world.

capacity building, protected area, biodiversity conservation, living laboratories, Colorado State University, Rocky Mountain National Park, U.S. National Park Service, Center for Protected Area Management and Training, US Forest Service

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Empirical Critical Loads of Atmospheric Nitrogen Deposition for Nutrient Enrichment of Mountain Lakes

The National Park Service has pioneered the concept of critical loads of air pollutants as a management tool for resource management. The critical load defines the level of atmospheric deposition below which there is no discernible effect, and can be used to guide protection or restoration efforts. The establishment of a critical load should be treated as an exercise in adaptive management and revisited often. As more data and better statistical approaches become available the values can be revised. We have now used two empirical methods to determine the critical load of atmospheric nitrogen (N) deposition to Rocky Mountain lakes that alters algal assemblages due to nutrient enrichment. Nitrogen-poor lakes will exhibit increases in productivity and shifts in the composition of phytoplankton in response to atmospheric N deposition. Our most recent effort looked for the inflection point where deposition amount, calculated three different ways, was related to increased lake N concentration for 531 mountain lakes of the Sierra Nevada, Rocky Mountains, and the Northeast US. The nutrient enrichment critical load for the Rocky Mountain lakes ranged 1.0-3.0 kilograms N per hectare per year, reflecting near-lack of watershed vegetation in complex, snow-melt dominated terrain. Encouragingly, the critical load developed using this method matches closely values obtained from biological hindcasting studies and correlative studies conducted by us and others. The mean lake N concentrations, when compared with the range of N known to stimulate productivity or alter algal assemblages, suggests that the N critical load is exceeded in some lakes of the West, including east-side lakes of Rocky Mountain National Park.

alpine lakes, nitrogen deposition, nutrient enrichment, critical load

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Log Jams and Carbon Storage in Headwater Streams in Colorado's Front Range

Historical documents and recent field studies suggest that resource use within the Colorado Rockies during the past two centuries has reduced the wood loads and frequency of wood jams along most forested streams. Log jams tend to slow the transport of carbon and encourage its uptake in the riverine environment and therefore may have effects which extend beyond stream. To evaluate possible changes, wood loads and jam frequency are compared based on stream characteristics, forest age, and flow alteration. In addition, sediment samples from reaches with and without log jams are compared based on organic matter (OM) content and Total Carbon (TC) content. Samples taken from behind log jams are compared to samples taken from other backwater areas along a river reach. Preliminary results of the 2010/2011 field seasons indicate that log jams on streams draining old growth forest (more than 200 years since last disturbance) average 45/km, while streams draining younger stands average 15/km. In addition, sediment samples taken from log jams (regardless of forest age) have an overall average of 5% OM, as compared to an average of 1% OM in samples taken from non-jam areas. Samples taken from log jams on streams draining old growth forests have an average of 12% OM.

carbon storage, log jams, instream wood

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Transport and Deposition of Reactive Nitrogen in Rocky Mountain National Park

Nitrogen deposition is a concern in many protected ecosystems and there are often few observations in these areas to understand the transport of key species. Measurements in and around Rocky Mountain National Park (RMNP) during several field campaigns provide insights into transport of pollutants in the region and important deposition pathways. The core site of measurements was located adjacent to the IMPROVE and CASTNet monitoring sites in RMNP. Measurements of reactive nitrogen included ammonia and nitric acid and ammonium, nitrate, and organic nitrogen in particles and precipitation. These data were examined for spatial gradients in concentration, the influence of wind direction on reactive nitrogen transported to the park, and their contributions to nitrogen deposition.

High concentrations of reduced nitrogen species occurred on the eastern plains of Colorado while oxidized nitrogen concentrations were highest along the Front Range. While winds were usually from the west, the highest 10% of nitrate and ammonium concentrations measured in RMNP were associated with upslope (easterly) transport pattern. During the measurement period sites were also located west of the park to observe background conditions. Concentrations of both reduced and oxidized nitrogen at RMNP were more than 50% higher than these background sites, again indicating large contributions from sources east of the park. Nitrogen deposition in RMNP is dominated by wet deposition of ammonium and nitrate, followed closely by dry deposition of ammonia and wet deposition of organic nitrogen. Both wet deposition of organic nitrogen and dry deposition of ammonia are not routinely included in traditional calculations of nitrogen deposition or the critical load. Nitrogen deposition for the year was 3.46 kg•N ha-1 for all pathways. The critical load for RMNP (1.5 kg•N ha-1) was set using only wet deposition of ammonium and nitrate. Deposition by these two pathways was 1.97 kg•N ha-1 for the year, well above the critical load.

nitrogen deposition, atmospheric transport, organic nitrogen

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A Sister Park Relationship: The Tatra Mountains of Poland and Slovakia and Rocky Mountain National Park, USA*

In September 2007, Rocky Mountain National Park signed a sister park agreement with the Tatra National Parks in Poland and Slovakia. All 3 parks are mountain parks, International Biosphere Reserves and share mutual issues and concerns involving the conservation, preservation, and management of national parks, including natural and cultural resources, for the purpose of conservation, recreation and public education. Since 2007, we have engaged in numerous staff exchanges, conferences, initiated joint science projects and have shared numerous work products, lessons learned and ideas. . Since 2007, we have collaboratively cultivated relationships with five universities sharing research (three U.S., one Poland and one in Slovakia), The U.S. State Department has been a significant partner in our sister park success. To those who engage in the sister park relationship, there are unique and invaluable experiences gained that enhance careers and the protection of parks. Our experience suggests that a sister park relationship is time well invested. And, like many investments of relationship, the tangible benefits are shown over time as trust builds, shared visions evolve, and resources become available. For those who have been fortunate to travel abroad the experience has been career-changing; for those who spend time with staff from another country, their careers have been significantly enhanced. The future of protected areas management is global in nature. We believe the more we as individuals, as parks and as an agency embrace the sister park concept, the more relevant and protected our parks will be for future generations.

*as presented in: Bobowski, B., V. Baker. 2011. Rocky Mountain National Park's Sister Park Relationship. Pp 296-298. In: Fulfilling the International Mission of the National Park Service. The George Wright Forum. The GWS Journal of Parks, Protected Areas & Cultural Sites. Volume 28, Number 3.

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Shared Species of Rocky Mountain National Park, CO and Monteverde, Costa Rica: Connecting the Dots for Species Conservation

Sister cities Estes Park, CO, and Monteverde, Costa Rica are gateways to the protected areas of Rocky Mountain National Park (RMNP) and the Monteverde rainforest and cloudforest reserves. These areas provide important habitat for a variety of plant and animal species, including migratory birds. Many of the bird species that breed in RMNP migrate south during the winter, with some spending time or stopping in the Monteverde area of Costa Rica. Management collaboration across the boundaries of these and other seemingly unrelated protected areas is important to the conservation of shared species, especially as pressure from factors such as development and climate change increase. We will provide an overview of shared conservation strategies for this emerging program.

sister cities, migration, birds

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Butterfly Inventory and Monitoring in Rocky Mountain National Park

Long-term monitoring is of value to public lands. This citizen science inventory and monitoring project has over fifteen years of butterfly data for Rocky Mountain National Park. The species list grew from 94 to 140 confirmed species. Volunteers created a database with 78,765 butterfly sightings from 3,796 transect surveys. They also created a database with over 20 years of daily weather data from the National Weather Service Station, Estes Park 1SSE. Analysis is underway. Trends in the data may reveal butterfly life cycles on the local level, but no obvious correlation to environmental factors such as climate change have yet emerged. If we had stopped after eight years, trends in the butterfly communities would have led to the hypothesis that chemical deposition, elk, drought, or all three have affected the community's long term health. With fifteen years of data, the natural cycles of butterflies in the high elevation environment begin to be revealed. Even with relatively long-term monitoring, there is indeed danger of jumping to conclusions.

butterflies, citizen science, long-term monitoring

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Effects of Mountain Pine Beetle on 3 Species of Pines in Rocky Mountain National Park and the Front Range, 2009-2011

Epidemic populations of mountain pine beetle (Dendroctonus ponderosae; MPB) have not only killed trees throughout most of Colorado's lodgepole pine (Pinus contorta) forests since 1996, but have recently affected additional host tree species, ponderosa and limber pine (P. ponderosa and P. flexilis) east of the Continental Divide. In 2009-11, we conducted a collaborative study to investigate the impacts of MPB across a 200-mile area of the Front Range on lands managed by 9 federal, state, county, and city agencies, including Rocky Mountain National Park (RMNP). We measured MPB activity and tree/stand/site characteristics annually at each of 19 sites in mixed-conifer stands (4 at RMNP) and 36 sites in ponderosa-dominated stands (2 at RMNP) to evaluate 1) the extent of MPB selection and infestation of its 3 alternate host species (lodgepole, ponderosa, and limber pine) and 2) the influence of management practices such as thinning, burning, or no treatment on resilience of ponderosa pine ecosystems to MPB. Our results revealed considerable spatial and temporal variation in MPB impacts across the landscape, with 3 major trends. First, we found a striking north-south gradient of MPB-caused mortality in mixed-conifer forest (>50 % mean basal area (BA) of all pines killed in sites north of Estes Park, including 3 sites at RMNP, but <15% mean BA killed in sites further south, including Wild Basin). Second, there was less MPB activity overall in ponderosa stands treated by thinning (mean <2% total trees per acre (TPA) killed, as of 2011) compared to prescribed fire (e.g., 8% TPA killed at the RMNP burn site) vs. no treatment (e.g. 12% TPA killed at the untreated RMNP site.) Third, we found high levels of MPB activity in all pines at RMNP in 2008-9, but few new attacks in 2010 or 2011..

mountain pine beetle, ponderosa, limber, lodgepole

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Poster

A Study of the Effectiveness of Rocky Mountain National Park Elk and Vegetation Management Plan on Restoring Riparian Willow in the Core Elk Winter Range

Rocky Mountain National Park (RMNP) located in Colorado supports a vide array of wildlife, including several ungulate species. Elk (Cervus elaphus) are native to RMNP, however by the late 1800s they were extirpated from the area. In the early 1900's they were reintroduced and in the absence of significant predation or hunting the elk population flourished. A natural regulation policy that involved no active management within the park was instituted in 1969, with the belief that hunting in adjacent areas would control the elk population. In the ensuing years elk numbers increased and an observed change in vegetation occurred, particularly a decline in willow (Salix spp.) and aspen (Populus tremuloides) production. In response to the concern over the condition of the vegetation, in 2008 the Elk and Vegetation Management Plan (EVMP) was instituted within RMNP, conservation efforts include fencing, elk redistribution, vegetation restoration, and culling. In the current study twenty random plots were selected within fenced areas (exclosures) and unfenced areas within the core elk winter range. New growth, height, circumference and willow plot density data were gathered for all willow species in the plot. Average and total measurements from each plot were compared. Total measurements of individual plants show that in the fenced areas new growth, height, circumference, and plot density is greater than in the unfenced areas. Observations were noted on the health of the plant and the percentage of off-take (consumption), which showed by far healthier plants with more saplings within the fenced areas. Compelling evidence suggests that browsing in the unfenced areas does affect willow species' ability to thrive and reproduce; therefore maintaining the fenced areas does allow the plant communities to rebound. Evidence supports the idea that some factors of the EVMP are effective. However, there is no notable improvement in willow quality in the unfenced areas suggesting culling is not an effective management tool, and fenced areas may not be a long-term solution due to the need for ungulate consumption as a natural and necessary component to a healthy ecosystem.

elk management, over-browsing, Rocky Mountain National Park, Willow, elk browsing, riparian vegetation, National Park Management, core elk winter range

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Developing Transnational Sister-Park Cultural Resource Research Programs between Rocky Mountain National Park, the University of Northern Colorado, and the Tatra National Parks of Poland and Slovakia

In 2006, Rocky Mountain National Park signed an international sister-park agreement with two shared boundary national parks in the Carpathian Mountains of southeastern Poland and northeastern Slovakia. Since that time, the three parks (RMNP, Tatra National Park-Poland, and Tatra National Park-Slovakia) have exchanged park staff visits. In the past three years, faculty from the University of Northern Colorado and Colorado State University have visited Poland and Slovakian universities to explore collaborative mountain research programs in the natural and cultural sciences in the three countries. This paper describes an on-going initiative to develop cultural resource-based research and management-preservation projects involving Poland's Jagiellonian University, the University of Northern Colorado, RMNP, and Tatra National Park-Poland. It also describes the rich cultural heritages of the Tatra national parks and their potential for benefiting RMNP, and benefiting from, transnational cooperative research partnerships.

Rocky Mountain National Park, sister-park agreement, University of Northern Colorado, Jagiellonian University (Poland), Tatra national parks, cultural resource collaboration

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Review of Research Conducted in Rocky Mountain National Park of CO, USA and the Tatra National Parks of Poland and Slovakia

Rocky Mountain National Park (RMNP), a unit of the U.S. National Park Service (NPS), the Tatra National Park, Slovakia (Sprawa TANAP and Statne Lesy TANAP are further referred to as TANAP), and the Tatra National Park, Republic of Poland (TPN) have had a sister park relationship since 2006. The formal partnership agreement identifies commonalities in biological communities, geologic setting, and visitor issues. All three parks are recognized as International Biosphere Reserves by the United Nations.

Our initial goal was to highlight research conducted in RMNP and in the Tatra mountain range (both TANAP and TPN) as it relates to major research objectives, and to examine whether there are similarities or differences in the types of content categories being used to address those objectives. Research objective categories focused on for the purposes of this review included 1) natural history, 2) conservation, 3) management, 4) diversity, 5) response to disturbance, and 6) visitor-park interactions. Within these research objectives, subject content was further divided into categories including A) vegetation cover and change through time, B) herbivore-plant interactions, C) animal and insect ecology, D) hydrology, E) pollution F) carbon fluxes, sinks and sources, G) changes in soil quality, carbon accumulation, nutrients, H) physical processes: climate and geology, and I) effect of land-use changes and/or changes of pulse disturbances. Our final goal was to determine whether projects and results from these two similar mountain environments are of mutual relevance and to recommend areas of potential joint projects

Tatra National Parks, sister park

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Responses of Soil and Water Chemistry to Beetle Kill Induced Tree Mortality throughout Colorado and Rocky Mountain National Park, USA

Recently, bark beetles have caused widespread tree mortality across ~50 million hectares of coniferous forests from Alaska to Mexico including over 28,000 hectares in Rocky Mountain National Park (ROMO) by 2009 (47% of ROMO's forested area). This landscape-changing event may impact Colorado and ROMO resources by altering the release of nutrients to streams and lakes, with cascading effects on water quality, habitat, and biologic community structure. A study in Grand County investigated possible changes in soil and water chemistry in response to the bark beetle epidemic. Results from soil samples collected under trees in various stages of beetle-induced death indicated that soil moisture and soil nitrogen increased in soils beneath beetle-killed trees, reflecting reduced evapotranspiration and litter accumulation and decay. In the inlets to Grand Lake, no significant changes in stream-water nitrate or dissolved organic carbon were observed during 2001-2009. However, total nitrogen and total phosphorus increased, possibly due to litter breakdown or increased productivity related to warming air temperatures. Sampling in 2009 and 2010 across the Colorado Rockies showed a slight increase in concentrations of particulate phosphorus, but there were no statistically significant changes in dissolved phosphorus or any fractions of nitrogen or carbon. For the Grand Lake watershed and for regional sampling, multiple regression showed a weak response or no response of stream chemistry to beetle kill. In contrast to the large effects documented for other types of forest disturbance, tree mortality due to MPB infestation has minimal effects on stream chemistry in the Colorado Rockies. The weak response of stream water chemistry to beetle kill is explained largely by growth of surviving vegetation and changes in foliar chemistry, as well as the heterogeneous aspects (spatial and temporal) of this type of disturbance on nutrient release.

mountain pine beetle (Dendroctonus ponderosae); water quality; nitrogen, dissolved organic carbon

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Comparative Wetland and Alpine Ecosystem Processes in Rocky Mountain National Park and Tatra National Park, Slovakia

During 2011 we initiated cross continental comparisons of alpine and peatland ecosystems in the Colorado Front Range of Rocky Mt. National Park, and the High Tatra Mountains in Tatrzański Park Narodowy, Slovakia. These programs offer collaborative opportunities for researchers from the US, Slovakia and Poland to work with US National Park and Polish and Slovakian National Park staff and scientists to further cooperation and the use of scientific research to support resources management.

Goals of the alpine research, being conducted in collaboration with Dr. Jozef Sibik and Dr. Ivana Šibíková of the Slovakian Academy of Sciences, are to investigate the recovery of alpine ecosystems from domestic livestock grazing. A range of alpine areas in the Front Range have been investigated and additional work is planned for 2012. In the High Tatra Mountains where grazing practices are well known a gradient of sites ranging from those with long-term protection from grazing to those with recent grazing history are being studied. I will present an overview of these projects.

We are also investigating the influence of climate change and human activities on peat accumulating wetlands (fens) in the two regions. This work is being conducted in cooperation with Dr. Dominika Lewicka-Szczebak, Dr. Wojtek Drzewicki, and Dr. Piotr Jezierski from Wroclaw University, Poland. Ten fens in each area have been visited and peat cores and ground water samples collected for analysis. The goal of the analyzes are to determine whether recent or longer-term changes in peat forming processes have occurred. In RMNP the anthropogenic processes being investigated are historic ditching in peatlands as well as climate changes, and in the Tatra Mountains forestry practices, ski area development and drainage, and climate changes are being investigated. Several additional projects are being proposed. One would analyze the effects of beetle kill, logging, and fire on the carbon budgets of conifer forest floors. A second would develop long-term hydrologic and ecological monitoring of critical fens in Tatra National Park and zones surrounding the park that are important to park management.

sister parks, wetlands, peat, alpine grazing

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Poster

The Effects of Willow Condition on Wildlife Diversity in Rocky Mountain National Park

Many factors contribute to willow conditions including soil, length of growing season, nutrient concentrations, water table height, and effects from elk and beaver browse. Elk can decrease willow growth and size directly through herbivory, and indirectly by out-competing and reducing beaver, which maintain surface and groundwater levels as well as establishment sites favorable to willow. Over the past 50 years, riparian willow has been declining in Moraine Park and Horseshoe Park, which may lead to a decline in biodiversity and ecosystem function. RMNP's Elk and Vegetation Management Plan calls for fencing a portion of these willow communities to exclude elk herbivory and allow vegetation to recover. Park staff monitors the vegetation annually; however, few studies address the wildlife impacts of elk herbivory within riparian willows. Our research seeks to 1) determine bird and small mammal abundance and species richness on the two extremes of the continuum: healthy and unhealthy. 2) Survey exclosures to assess bird and small mammal abundance and species richness within elk exclosures. This information will contribute to the adaptive management process.

biodiversity, willow, elk browse, small mammals, birds, herbivory, water table

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Rocky Mountain National Park Waste Audit and Behavioral Change Intervention Initiative

Many federal, regional, and local municipalities and organizations have identified solid waste management, with a focus on landfill waste reduction, to be a core component of their overall sustainability operations. Rocky Mountain National Park (RMNP) is one such organization seeking to improve their landfill diversion rates. To begin this process, RMNP conducted a park-wide waste audit to determine which park location types have the greatest potential for waste reduction. The waste audit identified Family Campgrounds as the location type with the greatest capacity to increase recycling rates and opportunity to influence visitor behaviors concerning waste disposal. Moraine Park Campground was selected as the focus of a follow-on, two-year study. Community-based Social Marketing (CBSM) was used as the framework to identify strategies to increase recycling behaviors of park visitors. In accordance with CBSM, observations of waste disposal behaviors and intercept interviews with Moraine Park Campground visitors were conducted. The analysis of this data was performed using two qualitative data analysis techniques: Template Analysis and Constant Comparison. This analysis was used to identify the barriers and benefits to recycling and waste reduction in the campground. The main recycling barriers identified for park visitors include: sorting and procedural unfamiliarity, bin proximity and design, knowledge of recycling opportunities, and a lack of specific material recycling (e.g. paper). The cited benefits to recycling in the park include: environmental benefits (i.e. waste and resource reductions), connection to place, cleanliness, and a fulfillment of individual duties to preserve the environment for future generations. Based on these results, strategies to promote recycling behaviors include: gaining a commitment by visitors, facilities improvements to increase recycling convenience, and increased recycling awareness and visibility through the use of social diffusion and prompts. Next steps involve strategy implementation and a second waste audit planned for the summer of 2012.

waste reduction, recycling, community-based social marketing, sustainable behavioral change

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Rocky Mountain National Park Waste Audit 2011: Results and Recommendations

With 3 million visitors annually at Rocky Mountain National Park (ROMO), managing ROMO's facilities and infrastructure, while protecting its natural beauty, proves to be a difficult challenge. In order to improve ROMO's solid waste disposal program, an analysis of ROMO's waste stream was conducted via a waste stream audit and waste disposal site visits. Quantitative results from the waste audit show that there are great opportunities for improving waste diversion rates through increased recycling and composting initiatives. Qualitative results show that hazardous materials, uneaten food, and paper and plastic materials dominated park waste. Site visits noted a correlation between recycling rates and the visibility and accessibility of recycling containers. Recommendations to improve recycling rates and waste reduction efforts include increasing access to and visibility of recycling receptacles, improving recycling awareness and communication regarding ROMO's commitment to waste reduction, and strategies to encourage pre-sorting of recyclables by park visitors before approaching the waste disposal areas. Compostable materials accounted for a high percentage of waste across all of the audited location types and composting should be explored as an option to increase diversion rates. Further, infrastructure and awareness about the proper disposal of hazardous materials, such as propane canisters and batteries, is necessary to reduce or eliminate hazardous waste from entering the landfill. At the end of the 2012 summer season, a second waste audit will be conducted to evaluate the effectiveness of recommended and implemented waste diversion strategies implemented, and will help to identify further waste diversion opportunities.

waste audit, recycling, composting, facilities management, sustainability

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Effects of Selective Imazapic Application on Bromus Tectorum And Non-Target Species in Rocky Mountain National Park

Cheatgrass, a winter annual grass introduced from Eurasia, has invaded much of the Western United States over the last century. More recently, cheatgrass has become a threat to the montane and subalpine plant communities and ecosystems of Rocky Mountain National Park (RMNP). Cheatgrass aggressively invades disturbed sites and competes with native plant species by rapidly establishing a root system in early spring, depleting soil moisture and available nitrogen before many native species germinate. These characteristics make control of cheatgrass of primary importance when restoring disturbances within RMNP.

The purpose of this study is to determine the effectiveness of imazapic for cheatgrass control and its effects on non-target native species in grassland, shrubland and forest habitats. In 2008, 12 permanent monitoring plots were established in six imazapic treatment sites in RMNP, each with one reference and one imazapic treatment plot. Imazapic (23.6% a.i.) was selectively applied to cheatgrass post-emergence in 2008 and pre-emergence in 2009 and 2010, and application to native species was avoided. Plant species and functional group cover were estimated using modified Daubenmire cover-classes. Analyses were performed using a repeated measures analysis of variance (ANOVA) model. Cheatgrass was reduced more than fivefold to approximately 4% cover between 2008 and 2011 (ANOVA F-test, time and treatment interaction, $P=0.04$) in all vegetation types. There was no decrease in cover of native grasses, shrubs or forbs in treatment plots. In 2011 an increase in bare ground was detected in treatment plots (ANOVA F-test, time and treatment interaction, $P=0.02$) in all vegetation types. These results suggest that selectively treating cheatgrass with imazapic can effectively control cheatgrass while avoiding damage to native plant species. The increase in bare ground presents an opportunity to establish native vegetation while cheatgrass populations are diminished, potentially preventing cheatgrass reinvasion while also limiting soil erosion and nutrient losses.

cheatgrass, Bromus tectorum, weed, imazapic, Plateau, native, exotic

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Visitor's Concerns about Climate Change in Rocky Mountain National Park

Studies of the American public have shown a disconcerting lack of knowledge and concern regarding global climate change (Leiserowitz et al., 2010; Leiserowitz et al., 2011); however, this may not be the case with national park visitors. In this report we explore the difference

between Rocky Mountain National Park (ROMO) visitors and the American public with regard to knowledge, beliefs, and concerns about climate change impacts in ROMO. In the spring and summer of 2011 researchers administered 376 tablet based, on-site surveys to ROMO visitors (95% confidence interval).

Results indicate that most visitors believe climate change is occurring (72%), it is anthropogenic (43%), and that it will greatly harm the park (41%). Furthermore, the majority of visitors are currently noticing the effects of climate change in ROMO (63%), would like to learn more about these impacts (66%), and are willing to change their behaviors to mitigate these impacts (72%). Based on the visitor data, the authors suggest and discuss a number of innovative place-based strategies for engaging this unique public in the subject of climate change.

climate change, visitor research, survey, national parks, protected areas, Rocky Mountain National Park

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Population Genetic Analysis of Bighorn Sheep (Ovis canadensis) in Rocky Mountain National Park

This study focuses on a population genetic analysis of five bighorn sheep (Ovis canadensis) herds in and around Rocky Mountain National Park: Continental Divide, Never Summer, St. Vrain, Big Thompson and Mummy. The Mummy herd suffered a severe pneumonia outbreak in the mid 1990s followed by a significant die-off. Since that time, recruitment has remained low and the population has failed to rebound. One hypothesis is that this sudden reduction in herd size created a genetic bottleneck and subsequent inbreeding depression. Alternatively, environmental stressors such as malnutrition, disease and habitat fragmentation from roads or trails may also be driving this trend. Quantification of population genetic parameters allows us to test the first hypothesis using comparisons of genetic variation within each herd, differentiation among herds and estimates of gene flow within this metapopulation.

Non-invasive field collection techniques provided DNA for genotyping at 13 microsatellite markers as well as sequencing of two mitochondrial regions (COI and D-Loop). Analyses indicate that no herd, including the Mummy, shows a clear signal of recent genetic bottlenecks or inbreeding and that variation at individual microsatellite loci is generally consistent among herds. Comparisons of overall Fst values for both microsatellite loci and mitochondrial haplotypes indicate low population substructure. Pair-wise Fst values for both microsatellites and mitochondrial DNA show a pattern of increasing isolation by distance where the Continental Divide is a partial barrier to gene flow between herds. These data further indicate that gene flow is maintained primarily via ram migration while ewes are generally philopatric. These data are not consistent with the first hypothesis, but rather support the hypothesis that the Mummy herd's failure to thrive is likely due primarily to environmental factors. Thus, restoration efforts should be focused on ameliorating these potential causes while transplantation is unlikely to increase long-term persistence of these herds.

bighorn sheep, population genetics, microsatellites, mitochondrial DNA, inbreeding, metapopulation, gene flow

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Rocky Mountain National Park Hummingbird Survey

The project is an ongoing 10 year study of hummingbird populations and habitat in Rocky Mountain National Park (RMNP). The objectives of the survey are to collect demographic information for breeding and transiting hummingbirds; identify nesting and migration activities, document the presence of rare species; identify movement and dispersal patterns; obtain information on site fidelity and longevity; obtain information to improve gender identification of hatch year broad-tailed hummingbirds (Selasphorus [S.] platycercus); analyze field data collection results; and, prepare a well-documented record for future use. During the nine years of the project, field researchers captured, banded, measured, and released 10,278 hummingbirds of four species with 7,455 recapture events. Approximately 16,000 hours of field work and analysis have been devoted to the survey.

The breeding populations of broad-tailed hummingbirds are strongly influenced by over-winter environmental conditions in Mexico. Timing of arrival is affected by availability of early blooming nectar flower resources along migration routes and in courtship areas. Variations in the duration of courtship and nesting activities are a result of the effects of cooler or warmer spring temperatures slowing or accelerating nectar flower bloom. Relative annual fledging success is estimated from banding results. Recapture results for adults demonstrate a high degree of philopatry.

Transiting rufous hummingbirds (S. rufus) show considerable annual variation in total numbers and adult to hatch year ratios, indicating relative reproductive success for populations that move through RMNP each summer. Too few calliope hummingbirds (Stellula calliope) are captured to enable determination of population status. Recaptures of survey banded hummingbirds outside the park are providing evidence of migration corridors for broad-tailed and rufous species.

Molecular deoxyribonucleic acid analysis accomplished by USGS Fort Collins has developed initial markers for broad-tailed hummingbird hatch year gender differentiation to be matched with digital imagery of plumage patterns.

hummingbird, DNA analysis

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Restoration of the Grand Ditch Breach in the Upper Kawuneeche Valley of Rocky Mountain National Park

On May 30, 2003, the Grand Ditch, a trans-basin water diversion canal constructed in the late 1800's and early 1900s and located in the Upper Kawuneeche Valley of Rocky Mountain National Park (RMNP), breached its bank. The breach saturated an adjacent hillslope which gave way, creating a debris flow that sent a torrent of mud, rocks, and trees cascading down into Lulu Creek and the headwaters of the Colorado River. The damaged areas include upland, stream, riparian, and wetland habitats within an approximate 22-acre area, 1.5 miles in length. In 2008, the NPS won a $9 million settlement from the Water Supply and Storage Company, owners of the ditch, to restore the damaged resources. Beginning in 2009, RMNP began its National Environmental Policy Act (NEPA) process identifying the need to develop an Environmental Impact Statement (EIS) to access the impacts to a variety of resources for each restoration alternative. The goals and objectives for the restoration of the area are: to restore appropriate stream and groundwater processes, restore appropriate native plant communities, restore the stability of the hillside below the breach site, restore wilderness character, restore wildlife habitat, restore aquatic habitat, and to restore water quality in the affected area and downstream. An interdisciplinary team has developed four action alternatives (B, C, D, and E) and one no action alternative (A) for the subsequent restoration of the impacted area. Each alternative varies in the degree of restoration to be conducted, techniques used to implement the alternative, and the estimated restoration progress for ecological processes over time. A conceptual model for estimated restoration progress of ecological processes has been developed to show how each alternative meets the objectives and goals and the estimated number of years to reach those goals. A detailed presentation of alternatives will be shared and no decisions on restoration options have been made at this time. These decisions will be guided by the EIS currently underway.

Grand Ditch, nature conservation value, naturalness, forest structure, zoning, GIS

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Macro- and Micronutrient Transport in Frost Affected Soil, Rocky Mountain National Park, Colorado

The movement of macro- and micronutrients in frost affected tundra soils can influence high altitude plant communities and alter the trophic status of alpine lakes and streams. To evaluate the geochemistry of soil pore water in tundra soils, intact soil core samples were collected in Rocky Mountain Nation Park, Colorado (3680 meters). Collected core samples were kept frozen at -5oC until use, at which time the cores were warmed to 18oC over a 24-hour period. Columns were leached with low ionic strength water, and leachates were collected using a linear fraction collector. The leachates were analyzed for Ca, Mg, K, Na, Cu, Zn, Mn, SO42-, PO43-, pH, and select low molecular weight organic acids. Upon completion of leaching, the columns were allowed to drain, at which time the core samples were frozen at -5oC for five days. A total of six sequential freeze thaw cycles were used, the first three cycles involved a thaw, leach, drain, freeze cycle (-5o C, 5 days), the last three cycles involved thaw, leach, saturated column, freeze cycle (-5o C, 5 days).

Leachate analysis showed that P leaching within the tundra core samples was correlated to elevated Mn and oxalic acid concentration in solution. Release of P into solution may be attributed to the dissolution of manganese oxide solid phases adsorbing P, and the subsequent competition of P and oxalic acid for surface adsorption sites resulting in P leaching. Eluent P and Mn concentration in leachates were observed to decrease for the drained freeze-thaw cycle, and increase for the water saturated freeze thaw cycles. Copper and Zn were continually leached from the soil columns with metal concentrations being influenced by the water content of the freeze-thaw cycle. Magnesium leachate concentration decreased during the saturated freeze thaw cycles, while Ca showed no definite leaching pattern for either freeze thaw-cycle.

Chemical speciation of collected leachates indicated considerable metal complexation with oxalate, with Cu-oxalate complexes ranging from 4 to 62% of total Cu, and Zn-oxalate complexes ranging from 4 to 21% of total Zn. The extent of metal-oxalate complexation correlated with oxalic acid concentration in the leachates. The identification and quantification of aqueous complexes can be used to elucidate the mechanisms by which P is released and transported in tundra soils.

geochemistry, soils, macro- and micronutrients, Rocky Mountain National Park

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Ecotourism and Sustainable Development: Management Strategies of Rocky Mountain National Park

This research focuses on the issue of sustainable development and ecotourism at Rocky Mountain National Park. The research strives to examine and analyze the management strategies of Rocky Mountain National Park (RMNP) in developing ecotourism and sustainable operations in the park. A series of interviews were conducted with RMNP managers to determine their perspectives on sustainable development and ecotourism and planning for its development and activities. In addition, a number of interviews were conducted with outfitters and concessionaires to determine their activities in ecotourism and what RMNP can do to manage for sustainability. Comparison between the RMNP management and concessionaires questionnaire responses focused on several key issues; definition of ecotourism, trail conflicts, location of main souvenir/visitor center, bus service and carrying capacity for activities. Both groups agreed on what constitutes ecotourism and associated activities, problems with the location of the souvenir/visitor center and use of a bus system. There were differences of opinion in trail conflicts and carrying capacity of activities. The research presents a summary and analysis the questionnaire results and presents Best Practice (BP) case studies in the field of ecotourism and sustainable development and compares them to the current management strategies of RMNP's Master Plan. Based on the questionnaire feedback, the Master Plan strategies, and the Best Practices, it is believed that a monitoring and evaluation procedure would be beneficial to RMNP for developing future sustainable ecotourism management strategies.

sustainable ecotourism, management strategies, park planning

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Debris Flow Chronology and Analysis of Controls on Debris Flow Occurrence in the Upper Colorado River Valley, Rocky Mountain National Park, CO

The role of debris flows along the upper Colorado River was recently highlighted when the Grand Ditch, a 19th century water-conveyance ditch, overtopped from snowmelt and triggered a large debris flow along Lulu Creek, a tributary of the Colorado. Historical aerial photographs indicate that multiple debris flows have been triggered from the Grand Ditch over the last century. This study aims to determine whether the Grand Ditch has increased magnitude and frequency of debris flow occurrence from the west side of the Colorado River valley, as compared to the unimpacted east side. Ten distinct debris flows were mapped using aerial photographs and field exploration, dated from tree cores and tree scars, and analyzed for magnitude using heights of tree scars and estimated volumes of deposition. Forty scarred survivor trees and 38 cores from even-aged stands were dated, with corresponding debris flow dates ranging from 1923 to 2003. Six of the ten debris flow deposits are on the west side of the valley, with the largest of those along Big Dutch Creek containing an estimated 50,000 m3 of sediment and dating to 1952. Debris flow occurrence appears to be clustered in groups that may correspond to breaches from the Grand Ditch or fire followed by intense rain. Additional factors used to evaluate controls on debris flow deposition were basin area, hydrothermal alteration of source rock, slope, and aspect, with basin area emerging as a strong control. Although the debris flow record is limited by frequent disturbance and burial of older deposits, and estimates of magnitude have high uncertainty, these data suggest that the Grand Ditch has contributed to the occurrence of larger and more frequent debris flows. This study demonstrates the applicability of dendrochronology for dating geomorphic events in Rocky Mountain National Park and provides context for debris flow restoration.

debris flow, Colorado River, Grand Ditch

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Influence of Digital Elevation Model Resolution on Terrain Based Hydrologic Parameters for a Subalpine Catchment, Front Range, Colorado

Understanding the reliability of digitally derived stream networks for mountainous areas is important to many water resource and land-use management applications. Digital elevation models (DEMs) have become an essential tool for mountain runoff analyses. Prior research has shown that accuracy of topographically derived stream networks vary both with the methods of calculation and the spatial resolution of the DEM used. As part of a larger study on stream networks for Loch Vale, a high-elevation catchment at Rocky Mountain National Park, we examine the influence of DEM resolution on spatially distributed topographic parameters important to stream network derivation. The analysis includes a comparison of local slope (tan β), specific contributing area (αs), and topographic wetness index (TWI) values derived from 1, 10, and 30m DEMs using both eight (D8) and infinite directional (D∞) flow algorithms. Results show that decreasing DEM resolution leads to a substantial loss of detail in spatial patterns of tan β, αs, and TWI. The D∞ flow partitioning algorithm also offers a visual improvement over the idealized network derived from D8. Statistically, using coarser DEMs and D∞ both shift the overall distributions of αs and TWI towards higher values. When applying minimum contributing area or TWI thresholds for channel initiation at Loch Vale, coarser DEMs result in a larger percentage of catchment area defined as channelized. Hydrologically, routing more water to channelized flow versus sheet flow or overland flow versus subsurface flow will result in shorter lag-to-peak times and higher overall peak flows in modeled hydrographs.

digital elevation model, channel initiation, channel networks

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Nitrogen Cycling in Loch Vale Watershed: the Microbial Role in Alpine Biogeochemistry

Loch Vale watershed represents a unique opportunity to understand fundamental aspects of alpine/subalpine biogeochemistry. We report a 30 year dataset that shows pronounced oscillations in mean, minimum, and maximum carbon:nitrogen (C:N) dynamics dissolved in the water column when all aquatic sites in the watershed are combined into a single analysis. Oscillating C:N values occur on approximately decadal time scales and are present in some but not all locations when sites are analyzed independently. We investigate the potential underlying drivers for these pronounced oscillations including: changes in precipitation, phosphorus dynamics, shifting insolation, and temperature. In addition we note that the bulk of the dissolved nitrogen is present as nitrate (NO_3^-) in the water column, however N enters the watershed as precipitation in about 50:50 ammonium NH_4^+:NO_3^- ratio. We use dual isotope analysis of the precipitation collected at the Loch Vale NADP Sites CO89 and CO98, in the snow pack, and at multiple sites within the watershed sampled in 2011, to determine if the NO_3^- is isotopically similar to inputs, or if the NO_3^- in the system is a result of microbial nitrification (conversion of NH_4^+ to NO_3^-). Understanding the underlying drivers of dissolved nutrient dynamics in Rocky Mountain National Park is a prerequisite to projecting how global change is altering the ecosystems.

ecosystem, watershed, nitrogen, microorganisms, future

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The Never Summer Igneous Complex, Rocky Mountain National Park, Colorado

The Never Summer igneous complex, located in the vicinity of northwestern Rocky Mountain National Park, is one of the eastern-most manifestations of the mid-Tertiary ignimbrite flare-up, an event that affected much of western North America and produced some of the largest eruptions in Earth's history. Extensive glaciation of the Never Summer Mountains has resulted in a spectacular, ~2 km vertical exposure of the Never Summer batholith which consists primarily of the Mt. Richthofen granodiorite (MRG) in the north and the Mt. Cumulus granite (MCG) in the south. A few km to the west of the Mt. Cumulus stock, drill holes from a 1970s era molybdenum exploration encountered a body of granite porphyry, similar to the granite porphyries associate with the nearby Urad/Henderson molybdenum deposit. In addition to the plutonic rocks, a suite of volcanic rocks, consisting of early andesites, lahars, and rhyolite flows to culminating ignimbrites is well exposed in the area of the The Crater and Little Yellowstone. Uranium/Pb zircon data from the MRG and the MCG yield ages of 28.892 +/-0.014 and 28.02 +/-0.011, respectively and confirm that the emplacement of these rocks was contemporaneous with the adjacent volcanic activity (biotite and sanidine Ar-Ar ages ranging from 29.28 to 28.05 Ma). Geochemical and isotopic data obtained from the MRG indicate that the pluton is chemically zoned, as evidenced by a range in SiO_2 (55-66 wt %), εNd (0) (-2.0- -5.8), and $^{87}Sr/^{86}Sr$ (0.70490 – 0.71030). These variations likely reflect an original vertical zonation in the pluton which has subsequently undergone varying degrees of faulting and tilting. In contrast, the younger MCG and nearby granite porphyries are compositionally homogeneous high-silica granites (77 wt% SiO_2, εNd (0) ~-5.6, low Sr and Ba contents, and deep negative Eu anomalies), and are similar to the high-silica ignimbrites that marked the end of eruptive activity here at ~28.05 Ma. There is, however, no direct evidence of a link between MRG and MCG and any of the volcanic rocks. As a result, we conclude that the source of the magma that produced the volcanic rocks in this region must have been at greater structural depths than currently exposed at the surface (> ~2 km).

Never Summer Mountains, igneous rocks, ignimbrite flare-up

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Poster

Measurement of Soil Nutrient Concentration and Carbon Dioxide Production from Seasonally Frozen Alpine Tundra and Forest Soils

With increased nitrogen deposition and changing alpine climatic conditions, alpine soils will be exposed to environmental stress. The ability of alpine soil to support existing and new plant communities will be a concern. In addition, it is important to identify additional sources of carbon dioxide (CO2) that may be emitted from warming alpine soils. Soil nutrient and CO2 concentrations were tracked from mid-June to late-September 2011 at two tundra soil sites (a mineral soil and an organic soil) as well as an Engelmann spruce forest soil. Greater concentrations of nutrients were found at the forested site compared to the alpine tundra. Of nitrogen forms, ammonia was the greatest; nitrite and nitrate levels were insignificant. Each nitrogen form shows decreasing abundance through summer to fall. Calcium was the most abundant nutrient and was "very high" on average at the forested site. Low concentrations of nitrogen, phosphorus, and other elements combined with soils that are becoming increasingly acidic make it highly unlikely that in the future the tundra ecosystem will be able to support succeeding coniferous vegetation as well as existing wildflowers or tundra grasses. Carbon dioxide average about 2500 ppm at the forest site compared to 1000 ppm at the mineral tundra soil site and 1600 ppm at the organic tundra soil site. Carbon dioxide at the forest site was highest during June (≈ 4000 ppm), and later decreased and plateaued during the summer and fall (≈ 2000 ppm). Carbon dioxide production in the Engelmann spruce forest soil is roughly double that of the alpine tundra soil and the area of the forest is roughly 3 times the area of the alpine tundra. As a result, the coniferous forest soil has significant potential for adding additional CO2 to atmosphere.

soil, tundra, plant nutrients, carbon dioxide

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Interactions of Native Birds, Ungulates, Fungi, and Drought in the Decline of Riparian Willows

Willows are critical components of Rocky Mountain riparian ecosystems, particularly within Rocky Mountain National Park (RMNP), where they comprise the majority of the woody vegetation. Research on willow decline has focused primarily on the effects of elk browsing and altered hydrologic regimes controlled by beaver populations. However, other key stresses such as Cytospora spp. fungal infection and temperature induced late-season drought may be interacting in novel ways with these known factors. Field work initiated in the summer of 2009 examined willow community dynamics at the headwaters of the Colorado River in Rocky Mountain National Park, Colorado, where willow dieback is widespread. My research examines short and long term temporal scales of willow dieback to address two primary objectives: (1) To determine the timing and spatial scale of the dieback throughout RMNP and the Colorado Rockies and (2) To identify the interacting stressors leading to death of willow stems. Results have demonstrated that browsing by moose and elk plays a primary role outside of exclosures, where browsing levels are high. Sapsuckers, which rely on willows as a food source, play a major role in dieback of willows inside exclosures, creating a wound that can subsequently become infected by Cytospora spp. Currently, drought stress does not seem to be a dominant stressor, however, past drought events, such as the large droughts in the early 2000's may have played a role in the onset of the decline. Results of this research 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.

willow, sapsucker, Cytospora chrysosperma, fungi, ungulate browsing, drought

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Chemical Mediation of Penstemon-herbivore Interactions: A Comparison Among Colorado Populations

Plants produce a variety of chemical compounds that can function as a defense against natural enemies, such as herbivores. Plant chemistry depends on several abiotic and biotic factors including nutrient availability, plant genotype, and previous damage. Therefore, plants in the same species may vary widely in their chemical defenses and such variation can be evident at the

population level, as well as the individual level. Focusing on the native Colorado wildflower, Penstemon virgatus, my research assesses within and among population variation in defensive compounds for three tissue types: leaves, stems and flowers. Penstemon species are known to contain iridoid glycosides (IGs), defensive compounds easily detected using gas chromatography. I collected plants from six populations across Colorado, including two distinct populations within Rocky Mountain National Park. In the field, I quantified the amount of damage due to invertebrate herbivores visible on each focal plant, allowing me to quantify the relationship between plant chemistry and herbivore damage. Preliminary data suggests that individual plants are able to allocate different IGs into different tissue types depending on the location. Furthermore, populations analyzed thus far have shown wide variation in overall chemical defense, which may be due to the varying abiotic factors at each location, as all populations showed very low amounts of herbivory. By collecting data on natural Penstemon virgatus IG variation, I can predict how these native plants interact with local herbivores, particularly insects, and how these sources of variation may scale up to higher trophic levels.

plant-herbivore interactions, chemical defense, trophic cascade

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Poster

Nozone: The Dangers of Ozone in our National Parks

With the increasing impact of ozone on our national parks, this study compares ozone data from different national parks located in three different parts of the world. Using data from the Global Ozone Project (http://go3project.com/network2/index.php/pages/home), collected from monitors stationed in three separate locations (the Tatra Forest of Zakopane, Poland, the Montverde Cloud Forest in Costa Rica, and Estes Park, Colorado near Rocky Mountain National Park), the study analyzes which of the three locations has the highest ozone levels and which has the lowest ozone levels. The three monitoring sites are Sister Cities that have comparable upslope wind conditions with ozone that flows from a large city to timbered mountain region. The differences include types of vegetation, elevation, and point pollution sources. The researchers expect that of the average monthly highs Zakopane will be the highest and Costa Rica the lowest, and of the average monthly lows, Zakopane will be the highest and Estes Park the lowest.

ozone, air quality, sister cities, sister parks

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The Colorado Wickiup Project: Ephemeral Native American Wooden Features in Rocky Mountain National Park

Dominquez Archaeological Research Group (DARG) has been conducting the on-going Colorado Wickiup Project (CWP) since 2003, primarily in western Colorado. The project is a long-range effort to document wickiups and other aboriginal wooden features in the state, which are primarily attributable to the Ute and Arapaho Indians. The CWP has documented 406 wooden features (wickiups, tree platforms, etc.) on 83 sites. The findings have provided new insights into the final decades of the state's Native American occupants, including evidence of post-1880s off-reservation inhabitation. Phase VII of the project, in Rocky Mountain National Park, documented 37 wooden features on 20 archaeological sites that are considered of, or potentially of, Native American construction and dating to the late 19th and early 20th Centuries. These include 13 wickiups or conical pole shelters, ten cultural pole caches, five utility poles and racks, three lean-to shelters, two culturally modified trees, two firewood caches, a brush animal trap, and a windbreak. Two particularly well-preserved wickiups, sites 5LR12899 and 5LR12900, were newly recorded. A dialogue with Ute tribal consultants has been initiated and various options for the interpretation, protection, and long-range preservation of these rare and fragile structures are presented.

wickiup, cultural resources

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Mountain Biodiversity Patterns: What Do We Know So Far?

The abiotic and biotic gradients on mountains have enormous potential to improve our understanding of species distributions, species richness patterns, and conservation. I will describe how abiotic factors change with elevation, how flora and fauna respond to these changes, and how elevational species richness patterns have been studied to uncover drivers of biodiversity. On mountains around the world there are four main trends in elevational species richness: decreasing richness with increasing elevation, plateaus in richness across low elevations then decreasing with or without a mid-elevation peak, and a unimodal pattern with a mid-elevational peak. Each group of organisms (e.g., mammals, birds, plants) displays patterns on mountains that correspond to their ecological requirements and evolutionary history. I will discuss the history of elevational richness studies and overview the support for the various hypotheses thought to be important in richness trends, including climatic, spatial, biotic, and evolutionary factors.

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

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Prevalence and Effects of Chronic Wasting Disease in Elk from Rocky Mountain National Park

Chronic wasting disease (CWD) can have long-term, negative impacts on deer populations, but there is little known about the ecology of CWD in free-ranging elk (Cervus elaphus). We placed radio-collars on 136 adult female elk in Rocky Mountain National Park (RMNP) as part of a three-year study that measured the efficacy of rectal biopsies to diagnose prion infection and the impact of CWD on elk survival and population growth. Elk with biopsies that tested positive via immunohistochemistry (IHC) were euthanized, and postmortem samples were examined with IHC. Survival was monitored on a weekly basis and 20-34 study animals were resampled and euthanized annually. Specificity of rectal biopsies was 100%, while sensitivity was 74% when three or more follicles were obtained from the biopsy. Rectal biopsy test results were similar to brainstem samples, but neither tissue contained prions in the earliest stages of infection that were only detected in retropharyngeal lymph nodes. Minimum prevalence (% of elk infected) was estimated to be 9.9% (95% credible limits (CI) = 5.7, 15.7) based on rectal biopsies, but this estimate rose to 12.9% (CI = 8.0, 19.1) when we included four elk that were likely misdiagnosed at initial capture. Following removal of all known individuals with CWD, the annual survival rate was relatively high during the initial year of the study, but declined in subsequent years due to consistent increases in CWD-related mortalities (2008 survival = 0.97 [CI: 0.93, 0.99], 2009 = 0.90 [CI: 0.83, 0.95], 2010 = 0.85 [CI: 0.75, 0.93]). These results suggest that 1) rectal biopsies can be a useful research tool, but can miss elk in the earliest stages of prion infection; and 2) CWD can reduce the survival of adult females and slow the population growth of high-density elk herds.

Cervus elaphus, chronic wasting disease, Colorado, elk, mortality, prevalence, prion, survival

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Poster

Relative Sensitivity of the Seasonal Snow Zone to Climate Warming in the Western United States

Snowpack accumulation and timing of melt impact the availability of water resources for the Western United States. Climate warming could therefore significantly impact the hydrology of the Western U.S. by decreasing the amount of precipitation falling as snow and altering the timing of melt and associated snowmelt runoff. Therefore, it is essential to identify areas that may be especially sensitive to climate warming, so resource managers can take appropriate steps to plan for hydrologic changes. This study utilizes 11 year average (2000 – 2010) MODIS Snow Cover Area (SCA) data from January to July to delineate zones of intermittent, transitional, persistent and seasonal snow based on the duration of snow cover persistence. Within the seasonal snow zone, we use 11 year average (2000 – 2010) MODIS Land Surface Temperature data for January-February-March (LSTJFM) to categorize five different snow sensitivity zones. Areas with the highest land surface temperatures are assumed to be most sensitive to climate warming, whereas areas with the lowest land surface temperature are assumed to be least sensitive. The snow zones in the highest sensitivity category occur at lower elevations of the Cascades and Sierra Nevada and in seasonal snow zones of the southwest, whereas snow zones with the least sensitivity to climate change occur in the interior northern Rockies, mid to higher elevations of the Cascades, and the higher elevations of the Colorado Rockies and the Sierra Nevada. These findings are comparable to other climate change sensitivity studies for the Western U.S.

climate change, snow, western u.s., sensitivity, hydrology

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Poster

Metagenomic Analysis of Seasonal Bacterial Communities in Alpine Soil of Rocky Mountain National Park

Alpine tundra forest soils are exposed to increased nitrogen deposition and seasonal climatic changes that could affect the growth of existing and new plant life. Therefore, it is important to assess potential impacts of changing climate on these ecosystems in regards to species diversity and abundance. While bacteria are usually unseen members of ecosystems, they can impact ecosystems through their metabolic processes. Some bacteria are a possible source of additional levels of carbon dioxide (CO2) with warming alpine soils. We are using genomics to identify bacteria present in soil samples collected at Rocky Mountain National Park. From these DNA studies, we will assess both genetic and metabolic diversity from these microbial communities. Our study is to identify the bacteria in alpine soil ecosystems at Rocky Mountain National Park. Soil was collected at three sites: two alpine tundra sites (one containing organic soil and one containing mineral soil) and one site located in an Engelmann spruce forest. Soil was collected from each site on three dates in June, July, and August 2011. We extracted DNA from each soil sample and used molecular techniques to build clone libraries of bacterial 16S ribosomal genes. We are in the process of sequencing bacterial clones from seven of the nine soil collections. At the time of the conference, we will present data of identified bacteria in the different soil collections. These and future studies may contribute to understanding how the diversity of soil microbes present during seasonal changes may affect nitrogen uptake and how they interact with and effect the surrounding plant community and composition of soil.

soil, bacteria, alpine, bacterial 16S, genomics

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Poster & Presentation

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Flying through ROMO's Geology – Integrating the NPS Geologic Resources Inventory Geologic Map with Google Earth

The National Park Service Geologic Resources Inventory (GRI), one of the 12 inventories defined and funded by the NPS Inventory and Monitoring Program, is tasked with providing each park with a digital geologic map in a Geographic Information System (GIS). While the GRI deliverable is a state-of-the-art GIS product, not all park managers and resource specialists have the necessary software or expertise to readily access it. To present the geologic map in a format familiar to most park staff, as well as the general public, the GRI team has developed a process to integrate the geologic map with Google Earth imagery of the park area, while maintaining the accuracy of the geology as well as all the traveling tools present in Google Earth. The resulting GRI Google Earth dataset, in KML/KMZ format, displays geologic data draped over elevation data and imagery and allows access to the data-rich feature attribute tables contained within GRI GIS datasets. Additionally, screen overlays and Google Earth balloons were developed to convey data sources, use constraints, and to provide links to additional information about the GRI, as well as other GRI datasets. This presentation will briefly identify the integration process and present a dynamic, three dimensional fly-through of the geology of Rocky Mountain National Park. In the following poster session, the integrated product will be available for additional, more detailed demonstrations to conference participants.

Rocky Mountain National Park, geology, geologic map, Google Earth, KML, KMZ

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Determining Environmental Drivers of Nitrification in Alpine Microbial Ecosystems

Remote alpine ecosystems exhibit vulnerability to anthropogenic drivers of change. A changing climate and atmospheric nitrogen (N) deposition alter temperature regimes, introduce nutrients, and influence hydrological processes. Long-term data from the Loch Vale watershed (LVWS) in Rocky Mountain National Park suggest headwater nitrate (NO3-) concentrations increase commensurate with warm summer temperatures. NO3- enrichment of nutrient-poor alpine lakes can result in increased primary productivity and diminished aquatic biodiversity. Nitrifying microbes strongly influence alpine N cycling and soil NO3- content, which may be flushed into alpine lakes. We hypothesized that terrestrial soil and sediment microbial communities are responding to shifts in temperature and moisture to produce NO3-. Soils and soil-like material were collected from newly-exposed glacier outwash, poorly-vegetated talus, and well-developed meadow substrate. All contained NH4+-N concentrations ~100x higher than typically observed in alpine soils. Because NH4+-N availability is the primary control of nitrification, we explored the effects of other important microbial drivers, namely temperature and moisture. All substrates underwent a 45-day incubation with substrate-specific temperature and moisture treatments in triplicate, during which net nitrification and microbial community dynamics were analyzed. Net nitrification increased with moisture in all cases. Outwash had the greatest nitrifier abundance and highest rates of nitrification. Nitrifier abundance increased with decreasing DOC, suggesting a competitive advantage in C poor substrates. These results indicate that nitrification responds predictably to changing moisture conditions, that alpine nitrifier abundance may be a good proxy for nitrification, and that newly-exposed sediments below ablating glaciers have high potential to increase NO3- levels in alpine lakes.

global change, atmospheric N deposition, nitrification, biogeochemistry

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Investigating Temporal and Spatial Patterns of Genetic Diversity in White-tailed Ptarmigan in and around Rocky Mountain National Park

The White-tailed Ptarmigan (Lagopus leucura) was recently petitioned for listing under the Endangered Species Act. Concern exists over the long-term viability of populations, given that alpine habitats where they exist are experiencing some of the greatest impacts due to warming climates. Ptarmigan are well adapted to these cool, alpine environments and the consequences of unusually rapid climate change are unknown. To begin to examine potential changes in population characteristics in White-tailed Ptarmigan over time, we investigated changes in genetic variation of White-tailed Ptarmigan from two time periods (1960s, and 2000s) for two populations in Colorado (Mt. Evans and Rocky Mountain National Park). We compared changes in microsatellite allele frequencies and levels of genetic diversity of feather samples collected in the 1960s with blood and feather samples collected in the 2000s. In addition to this temporal comparison, we are also investigating contemporary spatial genetic patterns within and around Colorado which provide important information about levels of gene flow and connectivity. Our research will provide insights into the connectivity between populations and the ability for birds to disperse between distinct populations. Additionally, when paired with on-going demographic and phenological work, we will begin to understand the potential for the species to cope with future climate change into the future.

White-tailed Ptarmigan, Lagopus leucura, genetics, microsatellites, genetic diversity, climate change

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Poster

FloZone: The Study of the Movement of Ozone in the Front Range to the Continental Divide

Research shows increasing ozone damage to alpine plants in Rocky Mountain National Park (RMNP). This study will use ozone data comparisons between four sites in Colorado: Denver (elev. 5435'), Estes Park (elev. 7255'), and Longs Peak Ranger Station (elev. 9,400') and the Ute Trailhead (elev. 11,466') in Rocky Mountain National Park. GO3 data will be used for Estes Park, CDPHE data for the Denver site, and Park Service data for the remote, high altitude sites at Longs Peak and Trail Ridge Road in RMNP to see if there is an established flow of ozone. If ozone is measured at different altitudes which follow upslope wind patterns then the times of ozone flow from Denver to the highest monitoring station will show fluctuations that indicate a flow pattern. Data from the four sites will be compared to analyze the transport of ozone from Denver to the various mountain sites at differing elevations. Various data comparisons will be presented to determine trends, including the timing of the peak ozone values at each site, as well as the average maximum and minimums to compare concentration values. The study will help RMNP understand how ozone is transported from Denver to the mountains, and whether the ozone tends to stay in valleys at lower elevations like Estes Park, or if it is transported to the high elevation sites in the park. Summer data going as far back as 2008 will be analyzed, subject to data availability at the four sites.

ozone, air quality

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National Park Service Pika Habitat Occupancy Study: Preliminary Results from Eight Parks

Identifying the American pika as a climatic indicator species, the National Park Service (NPS) has funded a project titled "Pikas in Peril: Multi-Regional Vulnerability Assessment of a Climate-Sensitive Sentinel Species." Vulnerability will be assessed by estimating how frequently pikas use different habitats and how the distribution of preferred habitats is expected to change under a range of climate projections. Specifically, this collaborative project will 1) document habitat use by pikas in eight NPS units (four parks in the Rocky Mountains and four in the Northwest), 2) estimate gene flow and connectivity among pika populations within five of those parks, and 3) project effects of climate change on the future distribution, connectivity and vulnerability of pika populations in each of the eight parks. Here, we report results from 2010 and 2011, the first two years of this three-year project. A consistent protocol for plot selection and survey was applied across all eight parks. Survey plots (each 24 m in diameter) were drawn from GIS-based sampling frames incorporating information on habitats, elevations, slope gradients and accessibility using a spatially-balanced random design. In total, 1178 plots were surveyed, including 266 surveyed in both years for analyses of pika gain/loss between years. Plots were classified as occupied if surveyors detected pikas (by sight or sound), fresh pika food caches and/or fresh pika fecal pellets within plot boundaries. The proportion of plots occupied ranged 0.34-0.71 for parks in the Rocky Mountains (0.45-0.67 in RMNP) and 0.07-0.65 for those in the Northwest. Detection probabilities were high (≥0.89) in data analyzed from pairs of independent observers. Although 1214 fecal samples have been collected for genetic analyses, sampling is ongoing in RMNP. Habitat associations will be analyzed and compared, where possible, to previous data from specific parks, and further reporting is planned for 2012 and 2013.

American pika, lagomorph, habitat occupancy modeling, GRTS design, detection probability, gene flow, climate change, vulnerability analysis

Will the Mountain Pine Beetle Outbreak Benefit Aspen?

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A recent outbreak of the mountain pine beetle has caused widespread mortality of lodgepole pine throughout Rocky Mountain National Park. In mixed aspen-lodgepole stands, this disturbance could potentially result in increased aspen recruitment. Research conducted in 2008 in RMNP found that aspen sucker density and average height were greater in areas with high lodgepole pine mortality. We re-sampled the same plots in 2011 to determine if aspen sucker density was continuing to increase, and to assess the potential for canopy recruitment. Sucker densities in 2011 were significantly lower than in 2008, and were not related to lodgepole pine mortality. Browse rates were high at all sites, and the initial pulse in aspen suckering has not resulted in any additional saplings. The mountain pine beetle outbreak is unlikely to result in increased canopy recruitment of aspen in areas where browse rates remain high.

mountain pine beetle, Aspen, recruitment patterns, growth release, browse pressure

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Ecosystem Changes after Pine Beetle and Salvage Logging in Colorado Subalpine Forests

Overstory mortality caused by current mountain pine beetle outbreaks in western North America surpasses both the extent and severity of most forest disturbances in recent history. The perceived increase in wildfire risk following beetle-related overstory mortality has prompted management aimed at reducing hazardous fuels. Here we compare forest regeneration, understory woody and herbaceous plant response and soil resources for a number of alternatives used for treating lodgepole pine-dominated subalpine forests that have been severely-impacted by bark beetles. Work was conducted at 24 sites distributed across northern Colorado where we compared untreated, beetle-infested stands to areas treated using lop and scatter, whole tree harvest, and whole tree harvest plus post-harvest soil scarification. Stand-level inventories were then used to project stand development, fuel profiles and potential fire behavior during the century after the bark beetle infestation. In general, logging increased soil moisture and nitrogen levels compared to uncut, beetle-killed stands. Native species cover declined in the first years after treatment compared to uncut areas. Retention of logging slash (i.e., lop and scatter) had positive effects on soil moisture, plant available nitrogen and tree seedling growth but inhibited the development of understory plants. Post-harvest activities aimed at increasing tree seedling colonization (i.e., soil scarification) increased total and inorganic soil N and extractable cations, but did not enhance seedling establishment or growth. Our model results predict that both logged and untreated stands will return to their pre-infestation structure in about a century. Salvage logging will regenerate pine-dominated stands similar to those that were infested by bark beetles. The species composition of untreated, beetle-killed stands in contrast, is likely to support a greater amount of subalpine fir; this species shift has implications for potential crown fire behavior and the processes that regulate soil productivity and the delivery of clean water from subalpine watersheds.

mountain pine beetle, subalpine forests, salvage logging, Colorado

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Poster

Visitor Injury Patterns in Rocky Mountain National Park: 2009 - 2011

Search and rescue efforts at the national parks are very costly and dangerous to the safety and health of the rescuers. By investigating the patterns of injury and fatalities, search and rescue efforts may be reduced, visitor injuries minimized and fatalities prevented. The purpose of this project is to analyze search and rescue data collected on Search and Rescue (SAR) reports for the years 2009 to 2011 at Rocky Mountain National Park. Specifically, we will identify patterns of visitor injury, visitor groups for targeted preventive search and rescue, identify factors contributing to the cost of search and rescue operations and compare injury rates to other national parks. Communication strategies from other parks will be evaluated. Communication campaigns and framework for implementation will be identified for the visitor groups.

visitor injuries, visitor safety, injury prevention, fatalities

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Land-use Changes in Alpine Areas: Intercontinental Comparison of Impact of Grazing on Alpine Communities

Alpine areas generally represent very sensitive biomes. These ecosystems are very fragile, even though the potential or real impact need not be intense. Our research has focused on the effects of grassland degradation and grazing on plant community composition and soil erosion in alpine areas of Rocky Mountains NP (Colorado, U.S.A.) and High Tatras NP (Slovakia, Europe). Alpine land use is as old as human presence in mountain foothills. Although the alpine flora of both, the Rocky Mountains and the Tatra Mountains has many congeneric or conspecific species, the evolutionary history of the floras was different. Moreover, the grazing history is different as well. Very little is known about the grazing history in mountains of the New World, but only a short history with non-extensive local-scale grazing is assumed. On the other hand, the grazing history in the Western Carpathians is well-documented and extensive grazing is known to take place since the Wallachian colonization in the 15th-17th century.

The decline of species-rich semi-natural calcareous grasslands is a major conservation problem

throughout Europe. Maintenance of traditional animal husbandry is often recommended as an important management strategy. However, results that underpin such management recommendations were derived predominantly from lowland studies and may not be easily applicable to high mountain areas.

The evolutionary history of grazing in alpine communities is not well understood but may have had only a minor role in structuring these systems. On the other hand, grazing can rapidly change species composition and morphology of communities. Thus, we aimed to determine the differences between grazed and non-grazed alpine meadows in both regions to test the null hypothesis that the species composition, morphology (structure) and ecology of alpine meadows was not determined by the evolutionary history of grazing. The second reason to focus on this problem was the knowledge that the recovery of disturbed alpine vegetation is very slow, thus we would like to point that out.

As methods, we used a series of plots along 500 m transects, with 1 X 1 m plots analysed every 25 m along each transect in areas with different grazing impact, as well as history. To date we have compared 5 localities – 3 in the Rocky Mts and 2 in the Tatras. The vegetation data has been gained following standard procedures of the Zürich-Montpellier School using the modified 9-degree Braun-Blanquet sampling scale. In each plot and transect subplot, several environmental characteristics has been recorded in addition to species cover. The percentage of bare ground (disturbed, open soil), litter (dead foliage) and rock (the amount of exposed rock) has been quantified in percentage. Height of the meadow vegetation (minimal, maximal and average) has been measured. Several plant traits have been observed and measured to study the plant responses to grazing: life history (annual, biannual, perennial), canopy height (short, medium, tall), habit (erect, prostrate), architecture (leafy stem, rosette, stoloniferous, tussock, cushion), growth form (forb, graminoid, herbaceous legume, woody), life form, phanerophytes, etc.) clonality (non-clonal, clonal aboveground, clonal belowground), spinescens (no spines, low, medium and high density of spines), palatability (palatable, unpalatable), dispersal mode (wind dispersed, etc.).

The preliminary results show that the regeneration of vegetation in Tatra Mts is more successful than in Rocky Mts. The soil erosion in alpine areas of Mt. Orton (Wild Basin region) still continue, in comparison with good regeneration in Belianske Tatry Mts. On the first locality, we can recognize the impact of grazing even after 100 years, while in Slovakia, the regeneration after 35 years is apparent.

The project will continue next summer and we will compare areas with well known grazing histories. The methods used will be extended with new ones like lichen-chronology to identify the rate of erosion in alpine communities and finally, the management remedies should be proposed to prevent additional erosion.

alpine communities, erosion, grazing, succession, vegetation changes

Rapid Forest Change Stresses Importance of Adaptive Management: A Case Study of Ponderosa Pine in western Rocky Mountain National Park, CO

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We studied a locally-rare population of ponderosa pine (Pinus ponderosa) in the North Inlet valley of the Colorado River drainage of Rocky Mountain National Park to investigate the role of rapid forest change in altering management options. Specifically, we were interested in how the recent mountain pine beetle (Dendroctonus ponderosae) outbreak in the area altered stand characteristics and resulting ecosystem management options. We documented the status (live or dead) of all ponderosa pine stems at the site and used dendroecological (tree ring) methods to identify relationships between disturbance events (i.e. fire, insect outbreaks) and ponderosa pine establishment. Over 80% of the approximately 400 ponderosa pine trees at the site were killed in the recent mountain pine beetle outbreak. Larger-diameter trees were killed and only smaller diameter trees, and saplings and seedling are alive at the site today. Over the past three centuries, ponderosa pine regenerated in pulses following infrequent fire events and it is not clear if insect outbreaks create opportunities for new ponderosa pine establishment. In the context of ecosystem management, prior to the outbreak fire would have been an ideal management tool to maintain ponderosa pine in the North Inlet; however, the current stand, which is dominated by seedlings, saplings and smaller-diameter trees that are not fire resistant, suggests that a fire at the site today could be a threat to the existence of the species at the site. Because this is the only population of ponderosa pine in western Rocky Mountain National Park and ponderosa pine is projected to be

a dominant species in the upper Colorado River Drainage under warming climate conditions, the management and conservation of the North Inlet population to provide a seed source for ponderosa expansion is likely critical for ecosystem adaptation to climate change.

ponderosa pine, pinus ponderosa, pine beetle, disturbance, fire, adaptive management

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Visitor Perceptions of Alternative Transportation in Yosemite and Rocky Mountain National Parks

Increasingly the National Park Service (NPS) is using alternative transportation systems (ATS) to accommodate escalating visitation. Understanding factors that influence visitors' transportation-related decision making is essential to developing effective management strategies that will not only decrease reliance on personal vehicles but also encourage shuttle ridership and improve visitor experiences. Survey research, conducted in Yosemite (2007) and Rocky Mountain National Park (2008) examined visitor attitudes toward the ATS experience. Three important factors: ease, freedom and stress, were identified by analyzing visitor data from each park using both exploratory and confirmatory factor analyses. The similarity in results between studies indicate that ATS related services, including infrastructure and messaging themes, could be standardized at RMNP and YOSE, and used to inform park management procedures at other NPS units.

alternative transportation, visitor attitudes, visitor management

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Poster

Improving Accountability for Scientific Equipment in Wilderness

Although much of the backcountry of Rocky Mountain National Park has long been managed as wilderness by policy, permanent Wilderness designation was legislated in 2009. The park has a robust research program with more than 120 permits annually, some of which involve installations and plots in designated wilderness. Over the last few years, park wilderness managers and research staff worked together to improve accountability of research activities in wilderness. Actions have included: 1) Setting up a database linked to a map layer and a photo file so research installations can be visualized and tracked; 2) Testing a simple system for assessing cumulative impacts by watershed; 3) Institutionalizing knowledge of science-based monitoring that can be used to track wilderness health; 4) Using the Minimum Requirement Decision Guidelines (MRDG) document recommended by the Aldo Leopold Institute for reviewing proposed research installations. Taken together, these actions have improved accountability for scientific activities conducted in the park's wilderness.

wilderness, research equipment, management

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Grouse, INC.

Population Demography of White-tailed Ptarmigan at Rocky Mountain National Park

Recent concerns over sensitivity of alpine ecosystems to climate change have brought attention to alpine endemic species. Investigating the impacts of climate on alpine species has been hampered due to a general paucity of available data, and assessing long-term trends of populations has not been possible in most cases. A population of white-tailed ptarmigan was studied from 1966 to 2000 at Rocky Mountain National Park by Colorado Parks and Wildlife. Analysis of this data indicated the populations significantly declined beginning in the mid-1970s. At least some of the decline has been attributed to warming winters, but the mechanisms underlying the relationship between winter temperatures and population densities is not well understood. Timing of nesting significantly advanced throughout the same time period due to warming springs, while reproductive success sharply declined. We reinitiated data collection of the previously studied population in 2010. Although population densities appear to have increased since the late 1990s, reproductive success remained low in both 2010 and 2011. Our current research focus is investigating local weather effects on reproductive success of white-tailed ptarmigan, and gaining a better understanding of the relationship between timing of nesting and peak resource abundance. Gaining an understanding of the mechanisms underlying observed relationships between climate and population demographics offers a promising route to forecasting future population trends.

alpine, climate, demography, weather, white-tailed ptarmigan

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Biotic Drivers of Multi-Thread Channels and the Carbon Cycle

Recent high-profile papers have highlighted the role that rivers play in the global carbon cycle. Of the terrestrial carbon delivered to rivers, less than half reaches the oceans. The remainder is returned to the atmosphere or sequestered in sediments. The balance among these outputs depends on how long carbon is retained in various storage sites along a river. Headwater rivers are particularly important in that they receive the majority of terrestrial carbon inputs. Despite recognizing the importance of riverine processes in the carbon cycle, many existing studies of carbon dynamics treat physical processes in rivers as a black box, focusing only on inputs and outputs rather than mechanisms within the river network. This talk uses the example of headwater rivers in Rocky Mountain National Park to examine the magnitude and spatial distribution of carbon stored in floodplain sediments, coarse organic material on the floodplain and in the stream, and living biomass on the floodplain. We partition river segments into distinct process domains as a function of their elevation and valley geometry. We find that laterally unconfined valley segments above the Pleistocene glacial moraines store disproportionately large amounts of carbon relative to their percentage of the total river length. Storage is enhanced by the presence of biotic drivers that force a multi-thread channel planform and enhanced overbank flooding. Biotic drivers can be either old-growth forest that facilitates the presence of numerous, closely spaced, channel-spanning logjams, or beavers and beaver dams. The interactions outlined in this talk have important management implications in that the biotic drivers that facilitate and maintain this carbon storage have been progressively lost over the past few decades.

headwater rivers, logjams, beavers, carbon dynamics

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Assessment of Rocky Mountain National Park Backcountry Campers' Adoption of Leave No Trace Technologies

Improper disposal of human waste (feces) in our National Parks is an increasing problem. In Rocky Mountain National Park alone, some 28,000 backpackers obtain permits for overnight or extended camping trips annually. We surveyed backcountry campers to assess their (1) demographics of respondents and backcountry camping characteristics, (2) camping activities and practices, (3) awareness and use of Leave No Trace practices, (4) views and perceptions of Restop2 bags and then (5) compare selected characteristics of Restop2 bag users with non-users.

We obtained a purposive sample (n= 227) of July and August 2011 RMNP backcountry campers and conducted a mail survey during late summer and fall 2011. In all, 122 (56%) returned the survey.

Respondents had a mean age of M = 39.27+ 12.87 years old, and 77% were males and 23% females. In the last 12 months, they camped an averaged 2.99+2.99 times and reported high levels of camping expertise and familiarity with the Leave No Trace Guidelines. While 96% of the respondents received the Restop2 bags, only 44 (37%) of the respondents used the bags. Of the adopters, 84% reported using the bags between 1 and 3 times and disposed of the bags using dumpsters at the trailheads or the trash and garbage. Advantages of Restop2 bags included ease of use, convenience, leaving less waste behind, and not needing to dig a cat hole, and disadvantages as being hard to use, carrying the bags out, being smelly, and weight.

We found no significant differences between users and non-users' understanding of the bag directions, opening the bag, closing the bag and using the gel. Users rated packing the bags our slightly higher than non-users and easier to dispose of them than non-users. The reasons for not using the Restop2 bags included availability of pit toilets, not needing them, or not wanting to carry them out.

backcountry campers, human feces/waste disposal, Restop2 Bags, Leave No Trace, camping

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Exploring RMNP visitors' information sources, communications, and perceptions of wildlife management practices

In fall 2011, we surveyed visitors to Rocky Mountain National Park to ascertain understand their (a) Knowledge of elk biology and elk impact on vegetation; (b) Awareness of proposed management practices—fencing, lethal controls, birth control methods, averse culling—i.e., controlled hunting; (c) Perceptions and attitudes toward the elk and vegetation management practices; and (d) Understanding elk and vegetation management practices. A systematic random sample of 615 participants entering the Beaver Meadows and Fall River entrances was gathered during the first weekend in October, the peak of the elk bugling season. Following the Dillman's (2007) Tailored Design Method, we used four mailings beginning mid October through mid December 2012. No token of appreciation was included. More than 70% of the volunteers/ participants returned the survey. The data have been entered into SPSS and we have begun analysis and interpretation. We will be ready to present the results of the survey at the Biennial Conference.

survey, knowledge elk biology & vegetation, elk management, understanding elk and vegetation management practices

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In Memory of our Colleagues

Dr. Ferrel Atkins
1924-2011

Ferrel Atkins had two parallel careers, one as a Professor of Mathematics and Computer Science (1952-1988), and another as a Park Ranger Naturalist-Historian. He worked at Rocky Mountain National Park from 1952-1984 and continued to volunteer at the park as "long as he was vertical", through 2010. Ferrel's sense of humor, encyclopedic knowledge of park buildings and history, and William Allen White lectures endeared him to multiple generations of co-workers and visitors. His unique contributions include the first survey of park visitors and a set of files compiling notes on park history, particularly buildings. Thus he provided pioneering contributions at Rocky Mountain National Park in social science and cultural resources. It is easy to imagine him in a rocker on a shady porch –with a view of a celestial Moraine Park.

Dr. James Benedict
1938-2011

Jim Benedict was legendary in Front Range archeology and geology circles but when you met the legend he was unfailingly polite and generous with his time. His primary area of interest was the Indian Peaks but he often strayed north into the park and held a RMNP research permit up until 2010. The park library holds 33 papers or books by Jim, though this is hardly a comprehensive collection of his contributions. He is perhaps most known at the park for his documentation of Trail Ridge Road game drives. During his last years he turned his attention to understanding what past climates might tell us about the impact of climate change on the future ecology of our area. Although Jim lived a relatively long life, his work and curiosity had not yet found their limits. The James (Jim) and Audrey Benedict Mountain Archeology Foundation at Colorado State University will continue the Benedicts' commitment to research, stewardship and public education. And Dr. Benedict's work will continue to serve as a basis for understanding both the geologic and human history of Rocky Mountain National Park.

Sheryl Costello
1977-2011

Sheryl Costello, a USDA Forest Service employee, died last summer in a climbing accident. Sheryl was a Forest Entomologist who took on problems with an energy and enthusiasm second-to-none, mastering the identification of the most difficult to discern species of bark beetles without hesitation. Park staff liked to kid her about our "hot trees." She would say our tree's aren't hot, which to her meant good looking, but instead were infested with beetles. Still at the start of her career, Sheryl was instrumental in connecting the NPS and the USDA as both dealt with bark beetle issues. Making such connections is not always easy in unwieldy federal bureaucracies but Sheryl's smile could easily leap over interagency obstacles and remind us of our shared interests. Her sudden loss left a place that is not easily filled.

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