National Park Service
U.S. Department of the Interior

Continental Divide Research Learning Center

Rocky Mountain National Park Research Conference 2006

Lindsey Nygaard photo

The Continental Divide Research Learning Center gratefully acknowledges the contributions of The Nerd Herd, volunteers who make park science happen.

Cover Photo: Researchers take the water temperature during amphibian research. Courtesy of Dr. Erin Muths, U.S. Geological Survey

Tuesday, April 4

9:00	**Coffee and Introduction: Science in the Park**

People and Places

9:20	**Rocky Mountain National Park Survey of Historic Resources** *Kris Christensen*
9:40	**Historic Trails of Rocky Mountain National Park, Phase II** *Sierra Standish*
10:00	**Clovis Hunting Bands and Late Pleistocene Deglaciation of High Mountain Tundra and Passes in Rocky Mountain National Park: The Case of La Poudre Pass** *Robert H. Brunswig, Ph.D.*
10:20	***break***
10:40	**Bison Paleoecology in the Alpine: Preliminary Results of the Radiocarbon and Isotopic Analysis of Two Bison Skulls Collected from a Melting Snow and Ice-patch in Rocky Mountain National Park** *Craig M. Lee*
11:00	**Estimating Visitor Use in Rocky Mountain National Park** *Matthew L. Bates*
11:20	**Quantifying Recreational Impacts Along the Glacier Gorge Trail in Rocky Mountain National Park** *David Pettebone*
11:40-1:00	***lunch***

Fauna

1:00	**White-tailed Ptarmigan: Ghosts of the Alpine Tundra** *Joyce Gellhorn*
1:20	**Avifaunal Responses to Fire Along a Burn Severity Gradient in Forests of the Rocky Mountains** *Natasha B. Kotliar*
1:40	**Assessment of the Status and Distribution of Wood Frogs and Western Chorus Frogs in the Kawuneeche Valley** *Rick D. Scherer*
2:00	**Cervid Use of Mineral Licks and Wallows: Implications for Disease Transmission** *Michael J. Lavelle*
2:20	***break***

2:40	**An Intensive Survey of Zooplankton in Rocky Mountain National Park and Preliminary Assessment of the Effects of Fish Stocking** *Toben Lafrancois*
3:00	**Mountain Lion Research in Northeastern Colorado** *Caroline E. Krumm and Don O. Hunter*
3:20	***break***
3:40	**Mountain Butterflies and La Nina: Selected Species Responses** *Richard O. Bray*
4:00	**An Assessment of Rocky Mountain National Park's Bear Population** *Roger A. Baldwin*

Visitor Experiences

4:20	**Visitor Satisfaction at Rocky Mountain National Park Along the Highway 7 Corridor** *Burke Grandjean, Ph.D.*
4:40	**The Senses at Rocky Mountain National Park** *Patricia A. Taylor, Ph.D.*

Earth and Water

9:00	**Age, Duration and Origin of the Never Summer Volcanic Field, Rocky Mountain National Park** *G. Lang Farmer*
9:20	**A Niche for Ice: Glaciers Resisting Climate Change in Rocky Mountain National Park** *Jon Achuff*
9:40	**Regional Geochemical Investigations in Rocky Mountain National Park by the U.S. Geological Survey, Mineral Resources Program** *Richard B. Wanty*
10:00	**Regional Biogeochmical Investigations in Rocky Mountain National Park by Colorado State University and the U.S. Geological Survey, Mineral Resources Program** *Travis S. Schmidt*
10:20	***break***
10:40	**Use of Chemical and Toxicological Methods to Assess the Presence and Potential Impacts of Polycyclic Aromatic Hydrocarbons Resulting from Recreational Snowmobile Use in Rocky Mountain National Park** *David A. Alvarez*

Vegetation

11:00	**Testing *Bromus tectorum* Influence on Arbuscular Mycorrhizal Fungi in the Field Using Restoration Strategies** *Helen Ivy Rowe*
11:20	***Bromus tectorum* (cheatgrass) at High Elevation: What Are the Roles of Intrinsic and Extrinsic Factors in its Spread?** *Erin Bard*
11:40	***lunch***
1:00	**Development of a Restoration Plan for Fan Lake** *Edward Gage*
1:20	**Mechanisms Maintaining Coexistence of Sympatric Cytotypes of *Arnica cordifolia* (Asteraceae)** *Rebecca Hufft*
1:40	**The Morphology of Protected Area Boundaries, Rocky Mountain National Park** *Geneva Williamson Mixon*

2:00-3:00

Poster Session

Hindcasting Nitrogen Deposition to Determine an Ecological Critical Load
Jill Baron

Ozone Risk Assessment on Susceptible Plant Species in the Rocky Mountain National Park According with the USA and Europe Union Criterions
V.M. Bermejo

Hummingbird Survey
Fred Engelman and Tena Engelman

Calculating Pre-measurement Atmospheric Deposition, Stream Chemistry, and Soil Chemistry for an Alpine Watershed in Rocky Mountain National Park, Colorado
Melannie D. Hartman

Controls on Soil Acidity in Loch Vale Watershed, Rocky Mountain National Park
Jill Oropeza

The Effects of Airborne Pollutants on Eumycetozoan Abundance and Diversity: A Preliminary Investigation
Dr. Rodney K. Nelson and Mary Jane Howell

Cost-Effectiveness Analysis of Restoration Approaches in Rocky Mountain National Park
Todd A. Ontl

Effects of Elk Herbivory on Alpine Plant Communities on the Elk Summer Range, Rocky Mountain National Park, Colorado: An Analysis of Existing Data
Linda C. Zeigenfuss

Air and Water

3:00 **Mercury Deposition, Transport, and Bioaccumulation in Rocky Mountain National Park**
D.H. Campbell

3:20 **Nitrogen Deposition and the Pattern of Soil Nutrients at Treeline in the Front Range of Colorado**
Daniel Liptzin

3:40 **The Effect of the Grand Ditch on the Abundance of Benthic Invertebrates in the Upper Colorado River**
Jordan Clayton

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A Niche for Ice: Glaciers Resisting Climate Change in 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. Comparison of recent photos with historical photos reveals a striking lack of overall change in the size and shape of these glaciers over the past century.

These tiniest of glaciers occupy environmental niches where snowfall, wind, cloudiness, exposure and elevation provide conditions suitable for survival of sufficient ice masses despite the ongoing and notable increase of overall global temperature. Currently, unlike many other glaciers around the world, these glaciers do not appear to be obvious or sensitive indicators of climate change accompanying observed global warming. However, this insensitivity reveals a set of buffering processes that interact to maintain these glaciers.

glacier, photography, climate change, alpine

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Use of Chemical and Toxicological Methods to Assess the Presence and Potential Impacts of Polycyclic Aromatic Hydrocarbons Resulting from Recreational Snowmobile Use in Rocky Mountain National Park

Emissions of contaminants, specifically polycyclic aromatic hydrocarbons (PAHs) from recreational snowmobile use in Rocky Mountain National Park, pose a potential hazard to the quality of the aquatic ecosystems in the Park. This project involved collecting and analyzing soil and sediment samples, use of integrative samplers to measure PAHs in water, and onsite toxicity testing at two ponds within the Park. One pond received snowmelt runoff from a nearby snowmobile trail and the other was a control pond with no known snowmobile activity. Two years of field work was performed in addition to the processing and analysis of samples in the laboratory. No differences in mortality or reproduction were observed among organisms exposed to water from the two ponds or the culture water. Chemical analysis of the sediments and integrative samplers did not indicate any significant differences in PAH concentrations between the control and test pond. In general, PAH concentrations were at background levels.

snowmobiles, toxicity, emissions, soil chemistry, polycyclic aromatic hydrocarbons (PAHs), recreation

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An Assessment of Rocky Mountain National Park's Bear Population

Black bears are one of Rocky Mountain National Park's (RMNP) most identifiable species, yet little is known about this population. Therefore, a study was initiated in 2003 to assess RMNP's black bear population and to relate associated population dynamics to habitat components. Initial effort focused on capturing and collaring bears, identifying bear home ranges, determining body condition, and estimating population size. These efforts will continue in 2006, but will be supplemented with dietary and habitat-use analyses. To date, 12 individual bears have been captured with 7 currently collared. This information, in addition to photos from remote-sensored cameras, suggests an overall population size of approximately 20 individuals. Results are preliminary, with further data collection and analyses to follow. However, current data suggest RMNP's bear population exists in suboptimal or temporally limited habitat resulting in low population densities, low recruitment, and large home ranges. Further investigation relating habitat utilization and body condition should help clarify this relationship.

black bears, population dynamics, habitat, home range, recruitment

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Bromus tectorum (cheatgrass) at High Elevation: What Are the Roles of Intrinsic and Extrinsic Factors in its Spread?

Sustainable management of non-native plants depends upon knowledge of the biological and ecological processes that lead to invasion. Determining the factors that enable introduced species to proliferate is as a fundamental challenge to ecologists and evolutionary biologists. Cheatgrass (*Bromus tectorum*) is an early-season, annual invasive grass that has great impacts on plant communities and ecosystems through altered fire regimes, competition with native plants, and interactions with microbial communities. Cheatgrass has spread to high elevations in the western U.S. over the last 10 to 15 years, raising concerns about the negative effects it will have on the newly invaded habitats. This range expansion may be due to intrinsic evolutionary change, such as local adaptation or phenotypic plasticity of all-purpose genotypes, or extrinsic environmental factors, such as changes in climate, increased local disturbance, nutrient enrichment, seed dispersal, or some combination of one or more of these mechanisms. There have been climate and nitrogen deposition changes that may facilitate the success of cheatgrass at high elevations and genetic factors may also be at work. In preliminary studies, germination of cheatgrass seeds from populations along an elevation gradient differed, exhibiting patterns that could be due to local adaptation. It is important to pursue knowledge about the relative roles of intrinsic and extrinsic factors in the range expansion of plant species such as cheatgrass. Through studying whether and how these factors are linked, we can develop more effective prevention, control, and restoration strategies, which will facilitate the sustainable management of natural areas in the U.S. Rocky Mountains and other high elevation regions.

cheatgrass, exotic plants, plant ecology, climate change, restoration

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Hindcasting Nitrogen Deposition to Determine an Ecological Critical Load

Using an estimated background nitrogen (N) deposition value of 0.5 kg N ha-1 yr-1 in 1900, and a 19 year record of measured values from Loch Vale (NADP site CO98), I reconstructed a N deposition history using exponential equations that correlated well with EPA-reported NOx emissions from Colorado and from the sum of emissions of 11 western states. The mean wet N deposition value for the period 1950-1964 was approximately 1.5 kg N ha-1 yr-1, corresponding to the reported time of alteration of diatom assemblages attributed to N deposition in alpine lakes in Rocky Mountain National Park. This value becomes the critical load defining the threshold for ecological change from eutrophication. Thus if a N deposition threshold for ecological change can be identified, and the date at which that threshold was crossed is known, hindcasting can derive the amount of atmospheric deposition at the time of change, at least for alpine lakes. Independent support for the technique and the deposition amount comes from experimental studies, ecosystem modeling, and paleolimnological records from northern Wyoming.

nitrogen deposition, critical load, Loch Vale, diatoms, eutrophication

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Estimating Visitor Use in Rocky Mountain National Park

It has been estimated that nearly 3.5 million people visit Rocky Mountain National Park (RMNP) annually. Such estimates are typically based on traditional counting methods such as cars at Park entrances or trailhead registers. Previous research suggests that trailhead registers are only moderately successful and estimate accuracy varies according to register location and the ease of filling out the form. Most automated trail monitoring systems have proved to be cumbersome, labor intensive, and inefficient. Although most overnight visitors in the backcountry pass through the Backcountry Office, there has not been a system plan for accurately estimating the total number of backcountry visitors in the Park. This study utilized active infrared monitors for estimating backcountry visitor numbers. The monitors were less problematic and more efficient at counting visitors than traditional methods. Results are presented for different use estimation zones that are

similar to management zones. The management implications of these findings will be discussed along with recommendations for the future use of infrared monitors in RMNP.

visitor use, backcountry, facility management, backcountry, infrared monitors

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Ozone Risk Assessment on Susceptible Plant Species in the RMNP According with the USA and Europe Union Criteria

Tropospheric ozone is a secondary pollutant that proceeds from the photo-reaction of nitrogen oxides and volatile organic compounds, such as hydrocarbons, in the atmosphere. It can reach high concentrations in rural and wild areas far from local sources of air pollutants. Tropospheric ozone is actually considered the most phytotoxic air pollutant. It can reduce the growth and reproductive capability of the plant species and can alter the biodiversity and structure of the ecosystems.

Actually there is a widespread agreement among plant effects scientists that simple ozone exposure concentrations measured outside the plant are not completely useful in relating to the corresponding plant responses. The ozone toxicity depends on its capability to reach the inside of the plant and it is related to meteorological parameters like temperature and humidity of the air or soil moisture that regulate the stomatal conductance of the plant. Lower ozone concentrations during wet weather can be worse for plants than higher ozone levels during dry conditions.

The ozone and meteorological data of the CASTNet site in the RMNP were used to calculate the Air Quality Standard used in the US and the Critical Levels defined in Europe to protect the vegetation against the effects of ozone. Both, together with the mean meteorological conditions during the growing season of the plants, are used to discuss the ozone damage risk of the susceptible plants growing in the Park

air quality, ozone, nitrogen, CASTNet, phytotoxic, stomatos

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Mountain Butterflies and La Nina: Selected Species Responses

The Rocky Mountain National Park Butterfly Project is a biodiversity study designed to provide baseline data on butterflies chosen to represent the “forgotten” 90% or more of the park’s fauna, invertebrates. The project, entering its tenth year, will provide ten years of data showing population fluctuations. Replication of the study in the future, when compared to this baseline data, will show long-term trends in the relative abundance of species populations. This baseline information is not presently available for the butterfly component of the park’s fauna. As such, it adds to park research designed to monitor ecological change in the park’s environment.

Project Description: Kilometer-long transects five meters wide are surveyed for butterflies once a week from May 1st through September 17th using the protocol described in Monitoring Butterflies for Ecology and Conservation (Pollard and Yates, Chapman and Hall: London, 1993). To allow replication of the transects in the future, the Universal Transverse Mercator coordinates of each transect are stored in a Geographic Information System using the North American Datum for 1927.

butterflies, population dynamics, biodiversity, climate change

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Clovis Hunting Bands and Late Pleistocene Deglaciation of High Mountain Tundra and Passes in Rocky Mountain National Park: the Case of La Poudre Pass

The earliest documented humans in Colorado's mountains and plains were part of a cultural population referred to as Clovis. Archaeological research by the University of Northern Colorado, starting in 1998 and continuing to the present, has established a small, but significant presence of Clovis people in Rocky Mountain National Park at the end of the Ice Age (Pleistocene). One of the park's archeological sites with Clovis evidence is on La Poudre Pass, along the continental divide on the northwest boundary of Rocky Mountain National Park and Arapaho National Forest. From 2000 to 2002 University of Northern Colorado researchers documented a large prehistoric site with Clovis and much later, Early Ceramic, components northeast of the pass. Around the same time, other Clovis sites were identified at similar high altitude Park sites, including one above Milner Pass. The La Poudre Pass site is perched on a glacial kame hummock of terminal glacial moraine deposits associated with the region's most recent (Late Pinedale) glaciation. Sediment core samples of peaty fen deposits in an adjacent kettle depression provided a detailed AMS radiocarbon-dated record of late glacial and post-glacial climate change from ~9710 b.p., evidence of rapid, significant early Holocene warming after the last pulse of significant Late Pleistocene glacial cooling (the Younger Dryas Episode). The presence of a Clovis point at La Poudre Pass and other Park sites, along with growing paleoclimate evidence, supports a picture of virtual deglaciation of the pass prior to ~11,300 b.p. and its use by Clovis hunting bands to cross the Continental Divide into the Kawuneeche valley and Middle Park beyond.

archeology, La Poudre Pass, Clovis, Early Ceramic, glaciation, radio carbon dating

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Mercury Deposition, Transport, and Bioaccumulation in Rocky Mountain National Park

Atmospheric wet deposition of mercury (Hg) is moderately high (6-10 mg m^{-2} y^{-1}) at high elevations of the Rocky Mountains, but little research has been done on the fate of Hg in these systems. We are investigating processes controlling Hg deposition, transport, distribution in the hydrosphere, accumulation in lake sediments, methylation, and bioaccumulation in biota as part of a number of different studies in Rocky Mountain National Park.

In the alpine watershed of Andrews Creek in Rocky Mountain National Park, Colorado, seasonal patterns and interannual variability in total Hg (THg) transport were investigated during water years 2003-2005. Most of the annual flux of THg was transported in dissolved form during snowmelt runoff, with both THg and discharge peaking during late June. Peak THg concentrations were associated with peak dissolved organic carbon (DOC), especially hydrophobic acids, being flushed from soils and other shallow groundwater matrices such as talus deposits. Concentrations of methyl Hg are usually near or below the detection limit of 0.03 ng L^{-1}.

Concentrations of Hg were measured in tissue of fish collected from 15 lakes and streams in the Park. Most fish had measurable Hg concentrations, but none of the trout had Hg concentrations exceeding the EPA guideline for human consumption of fish (0.3 ppm wet weight). Conditions in these alpine and subalpine watersheds generally do not promote bioaccumulation of Hg in fish: Low sulfur, low dissolved organic matter, and high oxygen levels limit production of bio-available methyl Hg in surface waters; and most trout in high lakes are not piscivorous, limiting potential for bioaccumulation associated with higher trophic levels.

Ongoing studies aim for better understanding of processes controlling methylation and bioaccumulation in high elevation ecosystems, in order to identify ecosystem components that may be most sensitive to atmospheric deposition of Hg. Interactions between potential future changes in Hg deposition, nutrient deposition, and climate in mountain environments are also being considered.

mercury, atmospheric deposition, Andrews Creek, bioaccumulation

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Rocky Mountain National Park Survey of Historic Resources

As required by Section 110 of the National Historic Preservation Act of 1966, as amended, Rocky Mountain National Park reviews its inventory of structures for potential eligibility of listing on the National Register of Historic Places. In this project, 45 properties were evaluated through the preparation of intensive survey documentation to determine eligibility. The project facilitates the update of NPS databases (including the List of Classified Structures and the Park's building database), as well as allow Rocky Mountain National Park to update its planning documents that relate to historic structures. This project was a partnership with the University of Colorado at Denver and Health Sciences through its College of Architecture and Planning and the Colorado Center for Preservation Research. An additional goal of this project was to provide an educational experience to students in the proper methods of architectural survey. A "for credit" course was provided, with eight graduate students participating. These students were pursing the historic preservation certificate at UCDHSC.

The properties surveyed have construction dates ranging from the late 1920s through the mid-1950s. The project identified six resources that are individually eligible for listing, and three districts. This study also found that many of the historic resources have lost integrity or lack historical significance. As a result they were found not eligible for the National Register of Historic Places.

Those properties and districts identified as eligible for the National Register of Historic Places can now be listed if Rocky Mountain National Park so chooses. Regardless of listing, the Park will have to comply with Section 106 of the National Historic Preservation Act, as amended, which includes review of changes to these properties by the State Historic Preservation Office.

National Historic Preservation Act, Section 110, historic properties, historic integrity, architecture

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The Effect of the Grand Ditch on the Abundance of Benthic Invertebrates in the Upper Colorado River, Rocky Mountain National Park

The Grand Ditch normally diverts around 50% of the annual snowmelt from the upper Colorado River watershed. In May of 2003, a 100 ft section of the ditch was breached, contributing substantially to the magnitude and duration of above-average discharge in the Colorado River through July. As a result, the gravel bed of the channel was fully mobilized, contrasting sharply with the minimal gravel transport experienced during the exceptional drought of the previous year. Thus, the 2002 and 2003 seasons provided opposing situations with which to evaluate the importance of bed disturbance for the maintenance of benthic invertebrate communities in a mountain river.

Macroinvertebrates were collected in the field at the same 6 locations for both years, and the number of individuals of the orders *ephemeroptera* (mayflies), *plecoptera* (stoneflies), *trichoptera* (caddisflies), and *diptera* (e.g. chironomids) was counted in the lab. From 2002 to 2003 the total number of individuals increased by 240%. In 2003, samples were also taken immediately upstream and downstream of a large flow obstruction in order to further isolate the relative importance of sediment transport against other variables affecting the stream habitat. Numbers of individuals were an order of magnitude higher at the upstream site than at the downstream, protected location.

These data demonstrate that there is a significant relationship between bed mobility and invertebrate abundance. It follows that the removal of the Grand Ditch would result in an increased frequency of bed disturbance in the Colorado River and the improvement of habitat conditions for invertebrates and trout species that depend on this food source. Furthermore, since east slope water demands were met while repairs of the ditch were underway by the re-routing of water via Big Thompson Project facilities outside the Park, the utility of the Grand Ditch as a diversion structure appears to be questionable.

benthic invertebrates, Grand Ditch, gravel, bed mobility, biodiversity, stream ecology

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Hummingbird Survey

The survey is a five-year volunteer citizen-science initiative project begun in 2003. The purpose is to document Rocky Mountain National Park (RMNP) hummingbird populations and associated habitat. The survey supports the National Park Service (NPS) *Science in the Parks* initiative. No NPS funding is utilized, although seasonal housing is provided. The survey requires approximately 2,100 hours for field research and report preparation each year. Survey objectives are to:

- collect demographic information for breeding and migrating species;
- identify nesting activity and note movement and dispersal patterns;
- obtain information on philopatry, longevity, and habitat;
- document plumage characteristics of hatch year *Selasphorus platycercus* (broad-tailed);
- document presence of rare or accidental species; and,
- translate collected data into publicly available information for use by park interpretive personnel and prepare information on hummingbird populations for future park applications.

The two researchers capture, band, measure, and release hummingbirds in designated locations on both the east and west sides of the Continental Divide using feeder traps and mist nets. A total of 2,276 hummingbirds of four species (*S. platycercus*, *S. rufus* [rufous], *Stellula calliope* [calliope], and *Archilochus colubris* [ruby-throated]) have been banded during the first three years.

Results so far include:

- Two significant foreign encounters have occurred, both involving *S. platycercus*. In the more important instance, a hatch year female banded in the Chiricahua Mountains of southeastern Arizona in September 2003 was encountered as an adult in RMNP in June 2004. The distance between the two sites is 630 statute miles, the current record for this species.
- The first *A. colubris* to be observed in the park was documented and supporting information was submitted to RMNP and the Colorado Bird Records Committee (record accepted).

A study of *S. platycercus* requiring deoxyribonucleic acid marker analysis is being pursued with Denver University.

hummingbirds, population dynamics, banding, migration patterns, rare species

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Age, Duration and Origin of the Never Summer Volcanic Field, Rocky Mountain National Park

High precision ^{40}Ar-^{39}Ar age determination from mid-Tertiary volcanic rocks of the Never Summer volcanic field demonstrate that volcanism was active here for only ~1 million years, from ~29 to ~28 million years ago. Volcanic activity commenced with small volume basaltic andesites, followed by the andesites to rhyolites now exposed in Little Yellowstone Canyon. Volcanism ceased with the eruption of the two large rhyolite composition ash flow tuffs exposed on Specimen, Lulu and Iron Mountains. These rhyolites, the upper and lower Iron Mountain Tuffs, and were likely deposited at ~28 million years ago. The total preserved volume of volcanic rock is < 20 km^3, several orders of magnitude less than the volumes of volcanic rocks produced at the same time in southern Colorado (the San Juan volcanic field). Neodymium isotope data for the rhyolites produced in the Never Summer and San Juan volcanic field are also very distinct and demonstrate that the rhyolites generated in southern Colorado incorporated large amounts of the preexisting continental crust prior to erupting. The upper and lower Iron Mountain tuffs contain larger proportion of material derived from the upper mantle. The contrast between the magmatic sources of rhyolites in the two areas suggests that the lower crust in southern Colorado was hotter in the mid-Tertiary than lower continental crust in northern Colorado. One possible explanation for this difference is that southern Colorado represented one of the major “drains” for magmas produced during the mid-Tertiary “ignimbrite flareup”, resulting in the heating of the lower crust during passage of large volumes of magma from the mantle to the surface. The Never Summer volcanic field represented only a minor

leak of mid-Tertiary magma through the continental crust, in an area distant from the region in which most of the mid-Tertiary magmatism in the southern Rockies occurred.

Never Summer Mountains, San Juan Mountains, volcanism, rhyolite, andesite

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Development of a Restoration Plan for Fan Lake

The 1982 failure of the Lawn Lake dam created a torrent of water flowing down the Roaring River, transporting vast quantities of sediment, much of which was deposited as an alluvial fan in Horseshoe Park. The fan impeded the flow of the Fall River, resulting in the formation of Fan Lake and flooding nearly 18 acres of riparian willow communities. Rocky Mountain National Park is interested in restoring the communities and ecological functions lost or impaired by the formation of Fan Lake, but requires a detailed site analysis to develop appropriate restoration goals and approaches. Our work was intended to fill information gaps by addressing the following questions: How does the site function hydrologically and are current hydrologic regimes suitable for the restoration of riparian willow communities? Are other constraints such as inadequate seed rain preventing natural recovery of the site? Where can willows be successfully planted across the landscape? Are there differences in the survival of willow cuttings among species or planting hydrologic regimes through realignment of the Fall and Roaring River channels, establishment of historic vegetation communities will be difficult to impossible. Based on these data and discussions with NPS personnel, specific restoration plans have been developed for the site.

Fan Lake, Roaring River, stream restoration, alluvial fan, hydrology, Lawn Lake Flood, riparian, willow

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White-tailed Ptarmigan: Ghosts of the Alpine Tundra

Elusive white-tailed ptarmigan are camouflaged to blend into their surroundings and are the only birds capable of survival at high elevations of Rocky Mountain National Park throughout the year. A slide program reveals life changes month by month and includes descriptions about where ptarmigan live, what they eat, their mating rituals, nesting, raising young, and molting patterns as they change from winter white to mottled brown in summer. The presentation also discusses unique adaptations of this species living in a harsh environment and problems facing ptarmigan as the climate changes.

ptarmigan, alpine, photography, adaptation, climate change

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Visitor Satisfaction at Rocky Mountain National Park along the Highway 7 Corridor

From October 2004 to the end of September 2005, visitors to Rocky Mountain National Park were interviewed to assess their experience and satisfaction with resources along the Highway 7 corridor. Approximately 1265 visitors were interviewed, with face-to-face intercept interviews taking place in the parking areas at Lily Lake (n=438), Longs Peak (n=414), and Wild Basin (n=413).

The respondents were asked a series of twenty questions regarding how satisfied they were with the availability of various developed resources in that area of the park. These resources included roads, restrooms, parking space, picnic areas, drinking water, scenic road pullouts, availability of park personnel, educational exhibits, hiking trails, camping sites, as well as other resources. After answering the questions on their level of satisfaction with the resources, the park visitors were then asked how the resources of the park might be managed so as to add more developed facilities, keep them as is, or even reduce the number of facilities. These facilities included most of the items in the satisfaction questions.

The visitors to the park were very satisfied with the park facilities and park management along the Highway 7 corridor, although there were differences by the site of the interview (Wild Basin, Longs Peak, and Lily Lake). Common among all three areas of visitation were lack of satisfaction with the availability of drinking water and back country toilets. The differences among the three areas will be discussed along with a breakdown by geographic origin of the visitor, and the number of visits to the park per year. These divisions revealed important differences among the visitors for park management decisions.

visitor satisfaction, Highway 7, Lily Lake, Longs Peak, Wild Basin, park facilities, park management

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Calculating Pre-measurement Atmospheric Deposition, Stream Chemistry, and Soil Chemistry for an Alpine Watershed in Rocky Mountain National Park, Colorado

Wet and dry deposition of N and S species have been measured for 25 years or less in the United States, making it impossible to know with certainty atmospheric deposition amounts from earlier in the 20th century. Likewise, measurements of ecosystem status, such as surface water chemistry and soil base saturation, for the first half of the 20th century are largely unavailable. We used DayCent-Chem, a daily timestep ecosystem-hydrogeochemical model, and daily historic VEMAP climate to investigate the changes in soil and stream water chemistry that may have occurred in an alpine ecosystem over the past century. Hindcasts of NO_3^-, NH_4^+, and SO_4^{2-} concentrations in precipitation were based on emissions of NO_X and SO_2. We ran DayCent-Chem from the known ecosystem state in 1999 backwards to 1900 to estimate stream water pH, stream acid neutralizing capacity (ANC), and soil base saturation that may have existed in the past. The model showed that mean annual stream pH and ANC were greater in 1900 than today, and that annual dynamics were highly responsive to SO_4^{2-} deposition. Minimum pH and ANC occurred in conjunction with the highest SO_2 emissions in the late 1960s-70s, before measurements began. Soil base saturation was higher in 1900 compared to the late 1990's. Over the past century, simulated stream [NO_3^-], like precipitation [NO_3^-], increased exponentially with NO_x emissions, while stream [SO_4^{2-}] reflected the interannual variability of SO_2 emissions.

acidification, nitrogen deposition, Loch Vale, stream chemistry, soil chemistry, ANC, modeling

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Mechanisms Maintaining Coexistence of Sympatric Cytotypes of *Arnica cordifolia* (Asteraceae)

Polyploidy is the process of genome doubling which gives rise to organisms with multiple sets of chromosomes. It is a central force structuring genetic diversity in angiosperms, yet its ecological significance is poorly understood. Theory predicts multiple cytotypes (organisms with different ploidies) of the same species should not coexist; yet sympatric polyploids are not uncommon. Coexistence mechanisms include: 1) reproductive assurance via selfing or parthenogenesis and 2) habitat differentiation. Little is known about how polyploidy influences habitat use, or how habitat differentiation influences polyploid production and distribution. I investigated the mechanisms contributing to the coexistence of triploids and tetraploids in the perennial herb, *Arnica cordifolia*. I assessed the frequency of sexual and asexual reproduction via apomixis to evaluate the potential for escape from minority cytotype exclusion. I quantified habitat differentiation between ploidies to test the hypothesis that triploids are being selectively maintained in disturbed habitat. Analysis of chloroplast sequence data revealed multiple origins of triploids and that Rocky Mountain National Park harbors a high diversity of genotypes relative to other areas surveyed for this work. This work informs us of the importance of polyploidy, parthenogenesis and habitat differentiation to the spatial structure of plant populations.

arnica, reproduction, population dynamics, polyploidy, habitat

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Avifaunal Responses to Fire Along a Burn Severity Gradient in Forests of the Rocky Mountains

I provide an overview of research on avifaunal responses to fire in montane and subalpine forests of the Rocky Mountains. This includes a study at RMNP on the response of the avifauna to prescribed fire in the ponderosa pine/upland shrub community (2002-2003). The Green-tailed Towhee was targeted because of concern by Park biologists that prescribed fire and subsequent ungulate grazing may negatively affect antelope bitterbrush regeneration. Green-tailed Towhee density and shrub cover were generally higher in unburned areas 3 - 5 years following prescribed burning. Opposing patterns were observed for nest-site selection and nest survival: increasing shrub cover led to a higher frequency of nests, but a decline in daily survival rates. Most species exhibited greater variation in densities, corresponding to spatial variation among sites, as compared to fire effects. These results are corroborated by the response patterns observed following wildland fires across the southern Rocky Mountains (Colorado/New Mexico) and Colorado Plateau (northern Arizona). Under moderate fire conditions, spatial and temporal variation in density associated with cover type and population fluctuations was often greater than the effects of burn severity. I present a model that characterizes the variation in response patterns across a burn severity gradient. Pre- and post-fire communities exhibited little turnover in species composition except in high-severity areas. Species richness was similar pre- and post-fire because the number of species absent in burned areas was balanced by species that only occurred post-fire. Our results indicate that management targeting the range of natural of variability, including severe fire where appropriate, is needed to provide dynamic habitat conditions for a diverse array of species. I also highlight proposed research that will help managers evaluate effectiveness among fuels reduction programs, while evaluating ecological effects of alternative approaches.

wildland fire, green-tailed towhee, population dynamics, fuel reduction

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Mountain Lion Research in Northeastern Colorado

An interagency collaboration has been established in northeastern Colorado to coordinate and integrate ongoing mountain lion (*Puma concolor*) research. Two main areas of study are underway. One focus is on the role of mountain lions in chronic wasting disease (CWD) ecology. Surveys conducted since 1996 have provided data on CWD prevalence in mule deer (*Odocoileus hemionus*) and the potential effects of selective population control on infection rates. Our current study tests the hypothesis that mountain lions prey selectively on mule deer infected with CWD. The other focus of study is on developing techniques for capturing and monitoring mountain lions in national parks. This study aims to learn more about the general ecology of the mountain lion in and around Rocky Mountain National Park. We are conducting research to better understand the value and appropriateness of new tools and techniques for mountain lion capture and monitoring. In conjunction with this work, we are evaluating new technology in Global Positioning Systems (GPS) tracking of animals (Lotek Wireless, Newmarket, Ontario and H.A.B.I.T. Research, Victoria, British Columbia) that allows location data to be downloaded remotely without retrieval of collars either from the field or via ARGOS satellite transmission. GPS-collared mountain lions from the prey selection study will aid in assessing the effectiveness of non-invasive techniques of monitoring mountain lion populations.

mountain lion, puma, chronic wasting disease, GPS collars

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An Intensive Survey of Zooplankton in Rocky Mountain National Park and Preliminary Assessment of the Effects of Fish Stocking

Fish introduction can change food chain structure, primary production, and water quality of lake systems. Studies of fish impacts on zooplankton of alpine lakes paint a mixed picture, however. In some cases, fish reduce the size, abundance, and distribution of zooplankton, sometimes leading to

extirpation of dominant species (such as *Daphnia middendorffiana*, found in Rocky Mountain National Park). Fish introductions have also been linked to changes in diversity, nutrient cycling, biomass, and other properties of lakes. On the other hand, some studies of alpine lakes suggest little or no effect of fish on zooplankton, and there can be 'positive' effects like increasing species richness. As specified by the Greenback Cutthroat Trout Management Plan, we surveyed the zooplankton of 33 lakes in July of 2005. Our goal was to assess differences in zooplankton species composition, abundance and biomass in order to determine the effects of fish along the widest array of other environmental variables.

In RMNP, fish influence both zooplankton size and community structure in a variety of ways. These effects, however, are complicated by other environmental gradients. It is not surprising that elevation, temperature, algal production and conductivity also explain variance in zooplankton communities. However, all four of these other factors roughly correlate with each other. Even more striking is that the presence of fish correlates (negatively) with elevation. So, while there are fish effects on zooplankton communities of RMNP, these effects must be understood in the context of a set of key environmental features. In this talk I will outline some of the more striking and important effects of fish and discuss the complicating factors and management implications.

zooplankton, fish, population dynamics, water quality, biodiversity, limnology

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Cervid Use of Mineral Licks and Wallows: Implications for Disease Transmission

Environmental deposition of prions, causal agents of chronic wasting disease, may contribute to disease transmission among free-ranging cervids. Discovery of environmental foci of cervid use and potential prion accumulation may provide clues for managing diseases. We conducted a preliminary study from 5 August to 14 October 2006 to evaluate the potential role of mineral licks and wallows in disease transmission. We used motion-activated cameras (n = 28) to capture behavior and interactions that could contribute to disease transmission at wallows (n = 22) and licks (n = 6). At mineral licks, we documented routine use (often daily) by multiple elk and deer of both sexes and all age classes. Though documented less often, moose also visited one of the commonly used mineral licks. Forty-three percent of wallows (12/28) were used sporadically by elk a few (1-3) times, half (14/28) were visited only once, and the remainder were not visited during the study period. Wallows, though more abundant, likely have lower potential for disease transmission than mineral licks. As routes of CWD transmission become better understood and decontamination methods are developed, there may be merit in focusing management effort on focal sites like mineral licks.

chronic wasting disease, cervid, disease transmission, mineral licks, wallows

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Bison Paleoecology in the Alpine: Preliminary Results of the Radiocarbon and Isotopic Analysis of Two Bison Skulls Collected from a Melting Snow and Ice-patch in Rocky Mountain National Park

In recent decades paleontological and archeological remains have been discovered in association with perennial snow and ice patches and glaciers throughout western North America. This paper discusses how these finds are reshaping our perception of alpine paleoecology and human prehistory, and provides exciting details about ongoing research on two bison skulls discovered in association with a melting ice patch in RMNP. The skulls, collected in 1981 by RMNP naturalist Dave Stevens, are curated at the Park's Museum. ROMO-6655, a nearly complete bison skull, dates to 680±15 RCYBP (CURL-8128). ROMO-6656, a more fragmented bison skull consisting of two

horn cores with horn sheaths, dates to 1095±15 RCYBP (CURL-8133). The discovery of fragile organic materials in association with perennial snow and ice features suggests these environments are experiencing atypical melting. Because such rare and irreplaceable specimens and artifacts rapidly deteriorate when exposed to the elements, there is an urgent, regional, need for focused surveys, similar to those conducted in Alaska (Dixon et al. 2005) and the Yukon Territory (Hare et al. 2004). Locations like RMNP, where diminishing snow and ice resources exist, may contain additional uncommon and informative materials such as those discovered elsewhere in the Colorado Front Range (Lee et al. 2006). Although no definitive association between the paleontological specimens and native peoples has been demonstrated, RMNP ice patches may yet prove to contain evidence of prehistoric human activity. References:

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archeology, paleoecology, ice patches, climate change, prehistoric, alpine

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Nitrogen Deposition and the Pattern of Soil Nutrients at Treeline in the Front Range of Colorado

Nitrogen (N) deposition is a growing concern in the high elevation ecosystems of the Front Range of Colorado. These ecosystems are thought to be on the verge of N saturation, especially east of the Continental Divide. Previous work in the subalpine forest has demonstrated that many ecosystem properties have been altered east compared to west of the Continental Divide (Rueth and Baron 2002). Likewise, in the tundra, many fertilization studies have suggested that the ecosystems have likely been altered by N deposition. However, treeline, which occurs at the transition between the subalpine forest and alpine tundra, may be particularly vulnerable to N saturation because of a unique unidirectional flux of materials transported by strong west winds. Trees at treeline are hypothesized to accumulate water, nutrients, and organic matter by functioning as snow fences, trapping materials blown from the adjacent tundra, including anthropogenic N. Thus, treeline might be a good indicator to monitor ecosystem status. We established transects at treelines where the vegetation boundary is abrupt, both east and west of the Continental Divide on both east and west aspects to determine if there was a pulse of nutrients near treeline. We predicted that this pulse of nutrients should be greater when the forest is downwind of the tundra (i.e. east aspects) and that nitrogen levels should be greater east of the Continental Divide. Contrary to our expectations, we did not find any indication of a pulse of nutrients at treeline. On some transects the soil nutrients changed abruptly at the vegetation edge, while on other transects there was a gradual change on both sides of treeline. Although there was considerable variability among sites, there was little evidence to support consistent differences related to either aspect or location relative to the Continental Divide.

nitrogen deposition, treeline, soil chemistry, Continental Divide, nutrient cycling, nitrogen saturation

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The Morphology of Protected Area Boundaries, Rocky Mountain National Park

A boundary typology for the park was created using GIS ownership data acquired from ROMO in June of 2004. The typology breaks the boundary into segments according to the ownership status of land adjacent to the park and provides a tool for pinpointing areas where cross-border management is expected to show the greatest difference. In the summer of 2005 fieldwork was conducted along the eastern border of the park focusing on the boundary segments that fell into type II of the typology (boundary adjacent to private land). A wide range of environmental variables (e.g. Canopy height, % bare ground, fences, etc.) were collected at over 400 observation points along the boundary. Panoramic photographic records were also collected at each observation point. Observations were recorded separately for the areas inside and outside of the park.

Preliminary results from geographic analysis of the data indicate that there are elements of distinct boundary morphology occurring along the park boundary adjacent to private land. The data also indicates that in some regions the area inside the park appears to be managed more intensely than the adjacent private land.

This research examines the extent to which human constructed boundaries, given sufficient differences in cross-border management, may manifest themselves as a generated edge (observable zones of ecological transition). Much of our understanding of these processes is theoretical. This research attempts to test the applicability of the existing theoretical framework to the real world. The results indicate that the type II ROMO boundary does exhibit some of the expected boundary effects although the location and distribution of those effects is at times surprising.

park boundary, GIS, private land, land management, photography

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The Effects of Airborne Pollutants on Eumycetozoan Abundance and Diversity: A Preliminary Investigation

The eumycetozoans or true slime molds consist of three groups—the protostelids, the dictyostelids (cellular slime molds) and the myxomycetes (plasmodial slime molds). Although an understanding of the specific ecological roles these organisms play in terrestrial ecosystems is as yet unclear, many researchers believe that members of the group (especially the myxomycetes) play pivotal roles in forest ecosystems. In one study, in which the influence of acid deposition on corticolous (those species associated with the microhabitat represented by the bark surface of living trees) myxomycetes in the city of Madrid in Spain was studied, assemblages of these organisms showed an inverse relationship with levels of atmospheric pollution. The numbers of both fruiting bodies and species recorded decreased with increasing pollution. Data from samples collected in Rocky Mountain National Park during the summer of 2005 were evaluated for myxomycete diversity and abundance. Preliminary indications are that differences exist in the assemblages of myxomycetes present, at least in certain microhabitats, between two existing paired study plots, one of which receives significant airborne contamination and the other of which receives relatively less contamination.

slime mold, air quality, terrestrial, pollution, population dynamics

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Cost-Effectiveness Analysis of Restoration Approaches in Rocky Mountain National Park

Rocky Mountain National Park has adopted guidelines that require the use of locally collected material in restoration projects to conserve the genetic integrity of plant populations. Areas disturbed through human activities are restored through natural revegetation, seeding, transplanting containerized material, or a combination thereof. Costs associated with these approaches vary considerably, emphasizing the need for an evaluation of the cost effectiveness of these methods in

the development of late-seral plant communities following disturbance. Vegetative cover and species richness were compared for disturbed sites treated with different restoration methods and associated undisturbed reference areas. Community similarity indices were also calculated for each disturbed/ undisturbed pair. Results show differences in the relative effect of treatments depending on criteria of effectiveness used, making a determination of Best Management Practices for restoration difficult. Similarity indices show seeded sites had the highest similarity while transplanted sites had the lowest similarity. Statistical comparisons of cover data showed that seeded sites had lower total and native species cover than other treatments. Species richness was not influenced by treatment. Cost-effectiveness analysis was based on actual total costs for individual sites and an Effectiveness Index (EI) calculated from cover data from each site. Analysis showed seeded sites are more cost-effective than other treatments in creating communities with high total and native species cover, while minimizing the establishment of introduced species.

restoration, native plants, disturbed sites, cost-effectiveness, seeding, diversity

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Controls on Soil Acidity in Loch Vale Watershed, Rocky Mountain National Park, Colorado

Many ecosystems of the Colorado Front Range including Loch Vale Watershed (LVWS), Rocky Mountain National Park exhibit symptoms of N saturation, a condition that can result in increased susceptibility of soil and surface waters to acidification. It is known that soils exert critical biogeochemical control over whole ecosystem processes; however, little is currently known regarding the capacity of LVWS soils to buffer changes in pH or their tendency to supply downstream environments with acidic drainage, nitrate and potentially toxic aluminum. The three main objectives of this study aim to improve our understanding of the LVWS soil environment and are as follows: 1) to determine factors that control pH for each of the dominant soil/vegetation associations, 2) to provide a current and comprehensive inventory of LVWS soil chemistry, and 3) to assess the effect of increased N loading on the soil chemistry and the factors controlling pH. Results of this study will contribute parameterization and partial validation data for ongoing biogeochemical modeling efforts, as well as provide a more complete understanding of the controls on soil acidity unique to forest, wetland and tundra soils and their likely response to N deposition.

nitrogen deposition, forest health, soil chemistry, Loch Vale, pH, acidification

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Quantifying Recreational Impacts Along the Glacier Gorge Trail in Rocky Mountain National Park

Protecting park resources and providing a quality visitor experience are goals of the National Park Service mandated by the Organic Act of 1916 and the Wilderness Act of 1964. Developing a study that measures physical impacts to park resources caused by recreation use can provide Park managers with information that can be used to protect the quality of visitor experiences.

Recently, Geographic Information Systems (GIS) have been used to create a spatially balanced probability based sampling plan to measure the proliferation of illegal campsites in Yosemite National Park (NP). However, this technique has not been used to sample other types of recreation related impacts. Therefore, the intent of this study was to create an efficient sampling plan to measure recreation related impacts in Rocky Mountain National Park.

This study addressed the following objectives: 1) Estimate the number of visitors along the Glacier Gorge trail; 2) Identify what types of impacts are occurring; 3) Identify where impacts are occurring. The results estimate that 450 visitors per day hiked to Alberta Falls, 190 visitors per day hiked to Mills Lake, and 42 visitors per day hiked to Black Lake. Social trail proliferation, litter, and vandalism were found to occur along the Glacier Gorge trail. These impacts were generally concentrated at destination locations, such as Alberta Falls and trail junctions. The average trail width for the entire

trail, including the Fire Trail, was approximately 4.5 feet and the average maximum trail depth was approximately 2.75 inches. Regression analysis of visitor use to trail width and visitor access to visitor use resulted in a high R^2.

visitor impacts, GIS, visitor use, Glacier Gorge, hiking, trail, recreation

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Testing *Bromus tectorum* Influence on Arbuscular Mycorrhizal Fungi in the Field Using Restoration Strategies

Cheatgrass has invaded approximately 40,000,000 hectares of rangelands in the United States, reducing native species diversity and transforming habitats. Cheatgrass continues to expand its influence and can now be found in montane ecosystems that are important habitats for wildlife and livestock. In addition to well understood mechanisms by which cheatgrass gains competitive advantage, recent studies show cheatgrass is associated with changes in arbuscular mycorrhizal fungi (AMF) communities. We test the idea that cheatgrass is associated with depleted mycorrhizal communities by implementing relevant restoration strategies, AMF and sucrose additions with seeding. Sucrose additions are a proven tool for initiating conditions that speed up successional change. The reduced plant available N suppresses annual plant species, including cheatgrass, and gives perennial species a competitive advantage. Because most perennial plants respond to AMF with increased growth compared to no AMF, if the AMF community is depleted, the addition of AMF with sucrose should have an additive effect on perennial establishment and growth. Sucrose amendments had the expected effect of reducing annual plant cover, increasing perennial seedling establishment, and minimally increasing perennial forb cover. Cheatgrass was inhibited by both sucrose and AMF amendments. However, we detected no response of native perennial species to the AMF additions. Despite increased awareness of the need to provide adequate AMF inocula to restoration sites, managers should be aware that sites in which native perennial plants persist may already have sufficient AMF. Although reduced mycorrhizal inoculation potential was found in the presence of cheatgrass, it seems that, at least where native species coexist with cheatgrass, the existing AMF can be adequate for successful recruitment of perennial species.

cheatgrass, restoration, mycorrhizal fungi, association, exotic plants, ecosystem health

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Assessment of the Status and Distribution of Wood Frogs and Western Chorus Frogs in the Kawuneeche Valley

The Kawuneeche Valley in Rocky Mountain National Park (RMNP) contains some of the largest subalpine wetland complexes in Colorado and is the only location where all four of the remaining amphibian species in the park are found. Results of recent research suggest potential threats to the amphibian populations in the valley. A water diversion ditch and drastically-reduced beaver populations have lowered groundwater levels in the valley, and consequently, have likely reduced and fragmented suitable amphibian habitat. High densities of elk in the park may also be contributing to the fragmentation. The purposes of my dissertation research are: 1) to provide managers at RMNP with baseline data for long-term monitoring of wood frogs and western chorus frogs in the valley, and 2) to use data on the current spatial distribution of wood frogs and western chorus frogs to test hypotheses that represent predicted responses of these species to recent alterations to the valley. I will describe this research project and present preliminary results from the first two field seasons.

amphibian, population dynamics, wood frog, western chorus frog, wetland, hydrogeology

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Regional Biogeochmical Investigations in Rocky Mountain National Park by Colorado State University and the U.S. Geological Survey Mineral Resources Program

The U.S. Geological Survey's Mineral Resources Program and Colorado State University have collaborated in the Central Colorado Assessment Project to provide comprehensive geological and biological science data and interpretations that will allow federal, state, and local land management entities to make informed land-use decisions in central Colorado. The study area extends through the central third of Colorado, from the New Mexico to the Wyoming borders, and from just west of Denver to Avon. Preliminary results of the biological and watershed science components of this study and for the Rocky Mountain National Park portion of the study are presented here.

Watersheds are complex systems comprised of terrestrial and aquatic ecosystems which function together to determine local stream geochemistry and aquatic communities. Variances in geochemistry and community composition are influenced by both terrestrial landscape gradients and longitudinal aquatic gradients. Most studies that investigate the linkages between aquatic and terrestrial interfaces do so by means of correlation. However, this approach does not fit the prevailing paradigm to which most aquatic and terrestrial ecologists subscribe: that watersheds are in fact complex hierarchical systems. We are developing geoenvironmental models descriptive of the influence of landscape gradients (i.e. geology, vegetation) on local-scale stream habitat, geochemistry, and community composition. We used Path Analysis and Structural Equation Modeling techniques to develop hierarchical covariance models descriptive of the geo-environmental interactions of watersheds from the Central Colorado Mineral Belt. The results will be models that emulate the interactions between the terrestrial and aquatic environment that may influence stream chemistry and ecology. These models will allow land managers to evaluate how management practices at the landscape scale influence local stream chemistry and ecology.

water chemistry, watersheds, land management, central Colorado, modeling, geochemistry

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Historic Trails of Rocky Mountain National Park, Phase II

Trails work is ephemeral. At Rocky Mountain National Park, most trails consist of dirt, wood, and rock—and are expected to succumb to harsh mountain weather and visitors' wear and tear. Even the best-built trails witness years of deterioration and reconstruction. After all of this change, how do you determine if a trail has retained its historic integrity?

In 2003, the park set out to determine just this. Specifically, the park surveyed its historic trails in order to evaluate their potential for nomination to the National Register of Historic Places. Background research indicated that trails in other national parks had retained their integrity based on their alignment, scenic backdrop, and style of construction. The transient character of dirt tread or log checks was deemed only an inherent aspect of trail building.

With this in mind, trails were considered for their association with three historic themes in Rocky Mountain National Park: tourism, landscape architecture, and travel. Modern trails were compared to historic maps, park reports and brochures, newspapers, photos and a trail crew diary. The Fern Lake Trail and the East Inlet Trail were nominated and, in spring of 2005, listed to the National Register. Using these two trails as a model, approximately fifteen more trails are being examined for their potential eligibility.

hiking trails, historic integrity, National Register of Historic Places, Section 110

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The Senses at Rocky Mountain National Park

From October 2004 to the end of September 2005, visitors to Rocky Mountain National Park were interviewed along the Highway 7 corridor and were asked a series of questions about their experience of RMNP through the senses of sight, smell, sound and touch. Approximately 1265 visitors were interviewed, with face-to-face intercept interviews taking place in the parking areas at Lily Lake (n=438), Longs Peak (n=414), and Wild Basin (n=413).

The visitors were asked whether their enjoyment of nature was affected by: human made smells, sounds, and congestion from other visitors. The respondents were also asked what senses were enjoyed during their visit to RMNP. For the great majority of visitors, their park experience was not affected by the presence of other people. However, the patterns in the responses by area of the park suggest some further areas of discussion for park managers.

Specifically, visitors to the Longs Peak area were more likely to feel there were too many visitors; visitors during the winter rarely expressed a feeling of crowding; and several visitors expected to see more wildlife.

visitor survey, visitor satisfaction, human senses, park management, congestion

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Regional Geochemical Investigations in Rocky Mountain National Park by the U.S. Geological Survey, Mineral Resources Program

The U.S. Geological Survey's Mineral Resources Program, has established the Central Colorado Assessment Project to provide comprehensive geoscience data and interpretations that will allow federal, state, and local land management entities to make informed land-use decisions in central Colorado. The study area extends through the central third of Colorado, from the New Mexico to the Wyoming borders, and from just west of Denver to Avon. The various components of the project address: geologic mapping; surficial, water, and bedrock geochemistry; topical and regional studies of water, mineral, and energy resources; and regional geophysical data. As a part of this project, we are developing a geochemical framework of the study area by examining stream environments and sampling stream water, sediment, biofilm, and benthic macroinvertebrates. To date we have collected samples from more than 150 sites. In the summer of 2005, we collected samples at 12 sites within Rocky Mountain National Park (RMNP) on both sides of the Continental Divide. These sites have been chosen to represent small watersheds underlain by specific geologic formations. For each sampled medium, we are conducting complete inorganic chemical analyses, and for a subset of the samples we are collecting aquatic insects.

Because we are primarily sampling first- or second-order watersheds, the waters are generally low in total dissolved solids (TDS), except in heavily mineralized areas, where acid waters with high concentrations of metals and sulfate may be found. In RMNP, the waters are generally very low in TDS, have circum-neutral pH, and low concentrations of most trace metals. Because of the minimal anthropogenic disturbance of watersheds within the park, we can focus on understanding water chemistry by modeling interactions between surface water and the rock over which it flows.

Other aspects of this project are examining aquatic macroinvertebrate populations and the occurrence of the invasive diatom *Didymosphenia geminata* in the context of the water-quality data. *D. geminata* was found in 7 of the 12 sites sampled within the park, primarily on the western side. Coverage of the stream bottoms ranges from present in microscopic quantities to forming nuisance masses.

land use, stream ecology, geochemistry, watershed, aquatic fauna, total dissolved solids

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Effects of Elk Herbivory on Alpine Plant Communities on the Elk Summer Range, Rocky Mountain National Park, Colorado: An Analysis of Existing Data

The majority of the elk (*Cervus elaphus*) population of Rocky Mountain National Park, Colorado summer in the Park's high elevation alpine and subalpine meadows and willow krummholz. The Park's population of white-tailed ptarmigan (*Lagopus leucurus altipetens*) depends on both dwarf and krummholz willows for food and cover. Concern about the effects of elk herbivory on these communities prompted the monitoring of 12 vegetation transects in these regions from 1971-1996. Over this 25-year period, data was collected on plant species cover and frequency and shrub heights. This data has not been statistically analyzed for trends in the measured variables over time to determine changes in species abundance. Krummholz willow species (*Salix planifolia*, *S. brachycarpa*) declined 17-20% in cover and ~25 cm in height over the study period. Graminoids (particularly *Deschampsia caespitosa*, *Carex*, and *Poa*) increased slightly from 1971-1996. No significant increases of non-native plant species were observed. An increase in presence of bare ground over the 25-year period warrants continued measurement of these transects. Lack of good data on elk density, distribution, or use levels precludes correlating changes in plant species cover, frequency, or heights with elk population trends. I recommend development of a more rigorously designed monitoring program that includes these transects as well as others chosen on a random or stratified design and consistent measurement protocol and sampling intervals. Some method of quantifying elk use, either through measurement of plant utilization, pellet counts, or census-type surveys, would allow correlation of changes in plant species over time with changes in elk distribution and density on the Park's alpine and subalpine regions.

elk, ptarmigan, summer range, herbivory, alpine, willow

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Happy Retirement to Park Science Officer Dr. Terry Terrell (seen above with Dr. William Weber)