National Park Service
U.S. Department of the Interior

Rocky Mountain National Park
Continental Divide Research Learning Center

2015 Rocky Mountain National Park Research Conference

Honoring the past, celebrating the present, and inspiring the future.

Welcome to Rocky Mountain National Parks' 7th Research Conference.

The world has become smaller. Issues of resource protection that once could be addressed within or near our National Park Service boundaries now extend across landscapes, oceans and continents.

The ever-increasing human footprint is shrinking habitats and species that once dominated landscapes. Like most change, it is often subtle to our daily experience; but the scientific evidence is clear – we are on the brink of a sixth extinction. It is now possible, more than ever, that protected areas may lose species before we can even identify them.

Foundational to finding a way forward is the ability of a protected area to connect from local to global scales of conservation. For a park to best protect those species and systems it is mandated to, it has to work at scales appropriate to its conservation – such as airsheds, watersheds, ecosystems, wildlife corridors, metapopulations, species ranges, and migratory pathways. Obvious to the solution, but not often addressed with rigor, is the fact that success in the biosphere is dependent upon *our* success with *our* ethnosphere. This fact should give us pause to understand better our environmental history, the diversity of cultures that once engaged this landscape, as well as those that do today. Simply, there lies much opportunity ahead of us.

And as we look towards the future, there also remains hope! This hope is born out of a past with numerous success stories where we have learned from history, recovered species, included a diversity of cultures, cleaned airsheds, rivers and waterways. But the tools we used in the past will not ensure a successful future; we must approach the future of park protection boldly, with inclusiveness, new ideas, and with a renewed connectivity to communities of support for the very place we all cherish.

Each and every year, for hundreds if not thousands of years before this wonderful park was established, people have come to experience its riches and for many, re-create themselves. I invite each of you to explore the ideas presented these two days and challenge yourself to engage! - engage in dialog, in science, in reflection, in diplomacy, in learning…..in transformation and action, towards a future for Rocky Mountain National Park that generations to come will celebrate.

--Ben Bobowski, Ph. D., Chief of resource Stewardship**,** Rocky Mountain National Park

We are pleased to announce our second research conference to undertake a Reduced Waste Initiative. Join us in making this effort a success by bringing a coffee mug and water bottle from home and using the recycling and compost bins throughout the building. 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.

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

We would like to thank the Rocky Mountain Conservancy for supporting the 2015 Research Conference.

2015 Research Conference Rocky Mountain National Park

Estes Park Municipal Building, 170 MacGregor Ave, Estes Park, CO 80517

Wednesday, March 4th — Morning

8:00 – 8:20 AM	Coffee and Mixer	
Room A: Welcome / Citizen Science, Science Literacy, and Youth Engagement		
8:20 – 8:40 AM		Conference Introduction and Awards Presentation
8:40 – 9:10 AM	Mark Fiege	**Keynote Address:** Thinking like a planet: "The Long Now" and the changing role of science and history in the National Parks
9:20 – 9:40 AM	Dan Cribby	Plains to the Park: Integrating STEM initiatives into national parks
9:40 – 10:00 AM	Mattie Horn & Kristi Lee	Rocky Mountain National Park and Santa Elena Cloud Forest Reserve student scientific and cultural exchange
10:00 – 10:20 AM	Break	
10:20 – 10:40 AM	Tena Engelman	Hummingbird survey, 2003-2012, Rocky Mountain National Park
10:40 – 11:00 AM	Chris Ray	Projecting futures for the American pika, a climate indicator species, in Rocky Mountain National Park
11:00 AM – 12:00 PM		**Conversation Café ****
12:00 – 1:15 PM	Lunch	
Room B: Current Management Issues		
9:20 – 9:40 AM	Kristen Kaczynski	Recovery of riparian vegetation in Moraine Park after the Fern Lake fire
9:40 – 10:00 AM	Mark Schutte	Geomorphic response of Fall River to the 2013 flood
10:00 – 10:20 AM	Break	
10:20 – 10:40 AM	David Pettebone	Trail use in Rocky Mountain National Park
10:40– 11:00 AM	Rebecca Urquhart	No park is an island – community collaboration
11:00 AM – 12:00 PM		**Conversation Café *****
12:00 PM – 1:15 PM	Lunch	

** The Conversation Cafe is a structured discussion time in which conference attendees rotate, at 20-minute intervals, among tables at which a specific topic is discussed. Please join us in a thoughtful discussion of Rocky's hot topics.

Wednesday, March 4th Afternoon

Room A: Climate Change		
1:20 – 1:40 PM	Aaron Piña	Prediction system for nitrogen deposition in Rocky Mountain National Park
1:40 – 2:00 PM	Glenn Patterson	Trends in accumulation and melt of seasonal snow in Rocky Mountain National Park
2:00 – 2:20 PM	Jason Sibold	Stability of spruce-fir forests in the Loch Vale watershed, Rocky Mountain National Park, USA
2:20 – 2:40 PM	Timothy Fegel	Biogeochemical signatures of alpine glacial and periglacial features throughout the American west
Room B: Aquatic Sciences		
1:20 – 1:40 PM	Ellen Wohl	The brief, tumultuous life of logjams in Rocky Mountain National Park
1:40 – 2:00 PM	Michael Venarsky	Western mountain streams past and present: the influence of forest stand age and logjam density on aquatic community structure
2:00 – 2:20 PM	Joshua Stepanek	Preliminary observations on the diatom (*Bacillariophyta*) flora of Rocky Mountain National Park: Summary of genera present and reports of new and interesting species
2:20 – 2:40 PM	Adam Herdrich	Effects of large woody debris and log jams on eastern slope rocky mountain trout populations
2:40 – 3:00 PM	Break	
Room A: Visitor Use and Wilderness		
3:00 – 3:20 PM	Jamie Krzeminski	Transportation and management strategies to reduce congestion in the Bear Lake Road corridor, Rocky Mountain National Park, USA
3:20 – 3:40 PM	Jeremy Schultz	Crowding among winter recreationists in Rocky Mountain National Park
3:40 – 4:00 PM	Colin Leslie	Measuring and monitoring wilderness character in Rocky Mountain National Park
4:00 – 4:20 PM	Ben Lawhon	Influences on future leave no trace behavior in national parks
Room B: Disturbance		
3:00 – 3:20 PM	Jean Fleming	The effects of bark beetle-fire disturbance interactions on post-disturbance forest regeneration
3:20 – 3:40 PM	Gregory Pappas	Understory vegetation response to mountain pine beetle-induced lodgepole pine mortality in Rocky Mountain National Park
3:40 – 4:00 PM	Ben Gannon	Montane forest structure and fire history, Colorado Front Range, USA
4:00 – 4:20 PM	Lindsay Ringer	Soil amendment application after road construction alters resource availability and can benefit native over non-native species

Thursday, March 5th Morning

Room A: Wildlife		
8:40 – 9:00 AM	Alison Ketz	Abundance estimation of elk in the Estes Valley, Colorado using a Lincoln-Petersen estimator with multiple data sources
9:00 – 9:20 AM	Dane Vanhoozer	The democracy of nature: culling American identity
9:20 – 9:40 AM	Jeffrey Christiansen	Application of mouse models to investigate chronic wasting disease
9:40 – 10:00 AM	Aimee Ortega	Prions in plants: assaying grasses from rocky mountain national park for PrP^{CWD}
Room B: Vegetation		
~~8:40 – 9:00 AM~~	~~Christa Sumner~~	~~Perceptions of bark beetle affected forests, Rocky Mountain National Park~~
9:00 – 9:20 AM	Anna Schoettle	Proposed limber pine conservation plan for Rocky Mountain National Park
9:20 – 9:40 AM	Scott Franklin	Forty-years of change in Aspen forests, Rocky Mountain National Park, USA
9:40 – 10:00 AM	Chris Davis	Managing cheatgrass with Imazapic in Rocky Mountain National Park: Lessons learned from a six year study
10:00 – 11:00 AM	**Poster Session**	
Room A: Birds		
11:00 – 11:20 AM	Shelley Spear	Factors influencing avian populations and habitat use in the alpine region of Rocky Mountain National Park, USA
11:20 – 11:40 AM	Kathryn Langin	How distinct is Rocky Mountain National Park's white- tailed ptarmigan population? Insights from a genetic analysis of park birds and beyond
11:40 – 12:00 PM	Jason Beason	Bird migration research at Rocky Mountain National Park
Room B: Historic Perspectives		
11:00 – 11:20 AM	Joshua Johnson	Understanding our spectacular mountain landscapes: A helium thermochronology study in Rocky Mountain National Park
11:20 – 11:40 AM	Mitchell Schaefer	To not impede nature: The transition from rustic to modern architecture in the national parks as represented by twenty structures at Rocky Mountain National Park, 1929–1962
11:40 – 12:00 PM	Jaci Wells	The McGraw conundrum: Preserving nature and culture in a historic landscape
12:00 – 1:15 PM	Lunch	

Thursday, March 5th Afternoon

Room A: Bears		
1:20 – 1:40 PM	Mark Vieira	Estimation of black bear density using hair snags along Colorado's northern Front Range
1:40 – 2:00 PM	Mary Kay Watry	Improving visitor experience by reducing bear confrontations and property damage in Rocky Mountain National Park
2:00 – 2:20 PM	Stacy Lischka	Understanding the effect of a large-scale bear-proofing effort on human-black bear conflict
2:20 – 2:40 PM	Kate Rusch	The Estes Valley bear education task force, a community collaboration to improve human and bear Interactions
Room B: Alpine and Subalpine		
1:20 – 1:40 PM	Bill Monahan	Forecasting the potential impacts of climate change, insects, and pathogens on limber pine in Rocky Mountain National Park
1:40 – 2:00 PM	Michelle Gibbons	Alpine restoration of Alpine Ridge Trail in Rocky Mountain National Park
2:00 – 2:20 PM	Jozef Sibik	The effects of grazing on alpine tundra: Intercontinental comparison of the Rocky Mountains (Colorado, U.S.A.) and the Tatras (Slovakia, Europe)
2:20 – 2:40 PM	Amber Churchill	Alpine moist meadow response to regional gradients of nitrogen deposition in the Rocky Mountains
2:40 – 3:00 PM	Break	
Room A: Fisheries		
3:00 – 3:20 PM	Chris Kennedy	History of the fisheries of Rocky Mountain National Park
3:20 – 3:40 PM	Scott Herrmann	Total mercury concentrations in 11 tissues of cutthroat trout from Lake Louise, RMNP, CO, USA
3:40 – 4:00 PM	Sierra Love Stowell	Genomics of inbreeding depression and genetic rescue of the last greenback cutthroat trout
4:00 – 4:20 PM	Thomas Detmer	The effects of introduced fish on invertebrates in lakes of Rocky Mountain National Park, USA
Room B: Air & Water Quality		
3:00 – 3:20 PM	Alisa Mast	Links between N deposition and nitrate export from a high-elevation watershed in the Colorado Front Range
3:20 – 3:40 PM	William Battaglin	Hormones, pharmaceuticals, pesticides, and other contaminants of emerging concern in water, sediment, and fish from Rocky Mountain National Park, Colorado 2012-2013
3:40 – 4:00 PM	Ashley Evanoski- Cole	Upslope air pollution episodes in Rocky Mountain National Park during the Front Range Air Pollution and Photochemistry Experiment (FRAPPE)
4:00 – 4:20 PM	Jill Baron	The abridged history of Loch Vale watershed research

Poster Presentations

Presenter	Title
Tracey Baldwin	The National Ecological Observatory Network at Rocky Mountain National Park
~~Karen Barton~~	~~Just listen: Connecting youth to nature using soundscape research~~
Ashley Bobowski	Citizen science at RMNP: A teenager's perspective
Katie Bobowski	Mercury at Rocky Mountain National Park: Why we should care?
Daniel Bowker	Challenges in obtaining quality atmospheric deposition samples in the Loch Vale watershed, Rocky Mountain National Park, CO, USA
Kelly Bricker	Bear Lake Road trailhead visitors of Rocky Mountain National Park, USA
Geoff Elliot	Rocky Mountain Conservancy – Conservation Corps and the next generation of public land stewards
Andrew Evans	Nitrogen and anion behavior in alpine tundra soil, Rocky Mountain National Park
Colleen Flanagan Pritz	Decadal trends in fish Mercury concentrations and comparison to health criteria, Rocky Mountain National Park, USA
Amy Goodrich	Reestablishment of vegetation on disturbed high mountain lakeshores following dam removal, Rocky Mountain National Park, USA
Sara Hamsher	The diatom (Bacillariophyta) genus *Nitzschia* Hassall in Rocky Mountain National Park
Jason Janke	Variability of annual and monthly soil temperature along Trail Ridge Road, Rocky Mountain National Park: 2008 to 2014
Kateryna Lapina	Ozone bioindicator gardens: An educational tool to raise awareness about the northern Colorado Front Range ozone pollution and its effects on living systems
Bridget Livers	Instream wood loads, channel complexity, and ecological potential in forested, headwater streams under alternative stable states in Rocky Mountain National Park
Laura Lutz- Zimmerman	Identifying natural resource constraints and opportunities for alternative recreation sites to the Bear Lake Corridor, Rocky Mountain National Park, USA
Andrew Martin	The genetic legacy of more than a century of stocking trout: a case study in Rocky Mountain National Park, Colorado, USA
Annette Patton	Upland processes and controls on September 2013 mass movements, Rocky Mountain National Park, CO
Jason Price	The chemical weathering of Calcium-bearing bedrock minerals in the Loch Vale watershed, Rocky Mountain National Park: Climatic warming and phosphorous dynamics
Charlie Repath	Grand ditch breach restoration: Phase 1
Holly Rogers	Piscicide effects on invertebrates in high-elevation lakes and streams: Establishing baseline
Russ Schumacher	Understanding and predicting meteorological conditions associated with high nitrogen deposition in Rocky Mountain National Park
~~E. William Schweiger~~	~~Long term monitoring of an imperiled resource in Rocky Mountain NP; the vitals wetlands~~

Presenter	Title
Nicholas Suftin	Geologic, biogeomorphic, and hydrologic controls on floodplain organic carbon retention in mountainous headwater streams of the Colorado Front Range, USA
Jennifer Taylor	Know your AQ: citizen-science air pollution monitoring & air quality education in Rocky Mountain National Park
Buck Unsderfer	Rare earth element enriched Pegmatite in Rocky Mountain National Park
Gregory Wann	Long-term reproductive success of white-tailed ptarmigan along Trail Ridge in Rocky Mountain National Park
Pam Wegener	Storage and flux dynamics for an active beaver meadow in the North Saint Vrain Creek, Rocky Mountain National Park, CO
Tyler Williams	The Implications of the Clark's nutcracker's (*Nucifraga columbiana*) use of space, foraging behavior, and caching behavior for limber pine (*Pinus flexilis*) metapopulation dynamics under multiple disturbance regimes
Sydney Wilson	End member mixing analysis: source contributions to Andrews Creek, Rocky Mountain National Park, USA
Shane Wright	Groundwork Denver Green Team: Exposing urban youth to opportunities within nation parks

Keynote Address

Thinking like a Planet:

"The Long Now" and the Changing Role of Science and History in the National Parks

Dr. Mark Fiege

Public Lands History Center / Colorado State University

Wallace Stegner Chair of Western American Studies / Montana State University

National parks face unprecedented problems stemming from rapid transformations in the global environment. In response, managers, researchers, and citizens are re-envisioning the purpose of research in the parks and the uses to which the sciences, history, and related disciplines can be put. My presentation will reflect on the past, present, and future of research in the national parks and the ways in which scientists, humanists, and their colleagues are reimagining parks as benchmarks of environmental quality, places of ecological work and experimentation, and sites at which to rethink the very nature of time and change.

Conversation Café

Join us for thoughtful discussions on some of Rocky Mountain National Parks' hot topics including:

Climate Change

Wilderness

Fisheries

Visitor Use and Experience

Wildlife Management

Next Generations

Disturbances

Submitted Abstracts (alphabetical order)

The National Ecological Observatory Network at Rocky Mountain National Park

Tracey **Baldwin** (National Ecological Observatory Network), Andrea S. Thorpe (National Ecological Observatory Network), and Jeff Taylor (National Ecological Observatory Network). Corresponding author:athorpe@neoninc.org

The National Ecological Observatory Network (NEON; funded by the National Science Foundation) is a continental-scale ecological observation platform for understanding and forecasting the impacts of climate change, land use change, and invasive species on ecology. NEON is designed to enable users, including scientists, planners and policy makers, educators, and the general public, to address critical issues and questions in environmental sciences. One of NEON's 60 terrestrial sites is located at Rocky Mountain National Park. The Park is one of several sites located along a gradient that provides the opportunity to compare how elevation and longitudinal position affect ecosystem response to climate change and atmospheric transport. In this talk, we will describe the scientific design, current status, and potential uses of NEON, including how scientists, educators, and others can 'plug into' NEON and utilize its data and infrastructure. We will also discuss how inclusion of Rocky Mountain National Parks enhances NEON's sampling design and the potential benefits of NEON's measurements for the park.

1. Honor the past: Provide a brief historical context for your work.

Research conducted at Rocky Mountain National Park has provided important insights for both management and conservation of the park and general understanding of ecological systems. Data collected in Rocky Mountain NP by the National Ecological Observatory will expand the ability of scientists and managers to understand the effects of land-use (in particular, the resulting effects of dust/nitrogen deposition), climate change, and invasive species on the ecology and hydrology of the park and other high mountain ecosystems and predict – and potentially manage for – future changes.

2. Celebrate the present: How is your work relevant to park visitors?

Ecosystem changes due to climate change, land use, and invasive species have the potential to impact visitor experiences in multiple ways. For example, it has been hypothesized that climate change will affect the abundance of ticks and the prevalence of tick-borne disease will increase, which will have negative implications for the health of visitors to Rocky Mountain NP. NEON's data will help park managers monitor, predict, and react in a timely fashion to ecosystem changes, potentially minimizing impacts to visitor experience.

3. Inspire the future: How might your work inform park management?

NEON will provide Rocky Mountain NP with freely available data (including site-based and remotely sensed data) and analysis packages to inform land management and conservation strategies for the park. By collocating measurements of soils, plant, insects, small mammals, and birds, NEON data can provide information to inform how ecosystem impacts, such as climate change and atmospheric deposition, cascade through trophic levels and impact the ecology and hydrology of the park.

Key words: *climate change, invasive species, land-use, ecosystem monitoring*

The Abridged History of Loch Vale Watershed Research

Jill **Baron** (US Geological Survey and Colorado State University) and the LVWS research team*. Corresponding author:jill.baron@colostate.edu

The Loch Vale research team includes more than 50 field and laboratory technicians, collaborators, and students. Recent Program Managers include Jill Oropeza (City of Fort Collins), Eric Richer (CO Parks and Wildlife), Jared Heath (City of Fort Collins) and Daniel Bowker (Colorado State University).

Acid rain was a hot topic when Congress passed the National Acid Precipitation Assessment Program Act in 1980. With support from the National Park Service, Man and the Biosphere Program, and absolutely no prior experience in biogeochemistry, I asked whether acid rain was falling in Rocky Mountain National Park, and if so, what effects there were. Selection and instrumentation of Loch Vale as the site for long-term monitoring and research in 1983 was the result of a combination of dumb luck and the results of a rigorous survey of water quality and catchment characteristics undertaken in 1981. Assigning roughly five minutes per decade, I'll explore some lesser known corners of Loch Vale research, including early studies of heavy metals and organochlorines, subalpine forest nutrient cycling and responses to nitrogen, wetland sulfur cycling, nitrous oxide fluxes from lake sediments, and ecosystem models of climate change and atmospheric deposition. A teaser of exciting current research will wrap up the talk. With more than 30 years of study, we return to the questions asked early on by Dave Stevens and Homer Rouse: haven't you learned enough yet, and why do you keep coming back?

1. Honor the past: Provide a brief historical context for your work.

National park research ca. 1960-1990 was inward-looking, addressing natural resource issues that could be managed from within. Acid rain changed that by disrespecting park boundaries and threatening resources with a pollutant no one could see. Alpine lakes in Rocky Mountain National Park were thought by all to be pristine; sadly we killed that assumption. Research into the effects of air pollutants and visibility in national parks was absolutely seminal to Title IV of the Clean Air Act Amendments passed by Congress. Everyone loves national parks and it was unthinkable that they were victim of careless power plant emissions.

2. Celebrate the present: How is your work relevant to park visitors?

Along with Silent Spring, Love Canal, and vivid pictures of flames leaping from the Cuyahoga River, acid rain horrified Americans. Instead of being fresh and cleansing, rain was suddenly poisonous. Our research showed that Rocky Mountain National Park received air pollutants that were fertilizing park resources and on their way toward acidifying lakes, streams, and soils. Unintentional fertilization of a crown jewel is a bad idea, and through strong science-management partnerships, air quality is today improving. This example shows the public how science informs management in a way that benefits not only parks but their surrounding regions.

3. Inspire the future: How might your work inform park management?

The legacy of 65 years of atmospheric nitrogen deposition persists in Loch Vale, even as air quality improves. Water quality responded rapidly to lowered atmospheric nitrogen deposition, but pools of this fertilizer remain in lake sediments and soils. We now study unexpected biological and chemical changes that we hypothesize are the result of interactions between warming and nitrogen availability. In this period of rapid global change, RMNP must manage its resources so as to protect its natural diversity and ecosystems. We continue to report findings to park managers so that they and we understand these phenomena and develop adaptation options.

Key words: *Loch Vale, atmospheric deposition, acid rain, climate change, lakes, soils, alpine, subalpine*

Just Listen: Connecting Youth to Nature Using Soundscape Research

Karen S. **Barton** (Geography and GIS, University of Northern Colorado) and Ben Baldwin (Rocky Mountain National Park).
Corresponding author: karen.barton@unco.edu or ben.baldwin@nps.gov

National parks and protected spaces are increasingly subjected to anthropogenic pressure resulting in reduced ecological condition including effects upon natural soundscapes. This project explores the relationship between active learning, the millennial generation, and soundscape preservation in two U.S. National Parks. The project aims to better connect undergraduate students to nature using active learning techniques and fieldwork as well as to understand how soundscape technology aids in place attachment and preservation of "acoustic libraries". Research results illustrate the importance of sound-based methodologies in contemporary citizen science programs geared toward today's youth.

1. Honor the past: Provide a brief historical context for your work.

Past geographical research on the ways in which people connect to nature and public lands through sound has not kept up with popular trends, particularly as this line of inquiry applies to youth. While the study of landscape lies at the heart of human geography, geographic research has been more attentive to the visual. In general, the social sciences have afforded an epistemological privilege to sight over hearing, and the majority of human geography is devoted to seeing the world, or speaking about it. And while ethnographic research has become central to cultural geography, focusing on the critical importance of the local or microscale, it nonetheless emphasizes the collection of visual images to accompany a researcher's detailed societal observations. This research emphasizes the importance of sound preservation within and beyond the geographic discipline.

2. Celebrate the present: How is your work relevant to park visitors?

From elk bugling to the sound of spring runoff, the soundscapes of Rocky Mountain NP provide visitors with a unique sensory experience of the park that goes beyond the visual. This research project focuses on the role that the millennial generation plays in gathering such sounds from public lands. Millennials - or those individuals born roughly between early 1980s to the early 20002 - increasingly play a central role in shaping the future of soundscape ecology. Their insights into the soundscapes and their associated methodologies will shed light on the challenges of acoustic preservation.

3. Inspire the future: How might your work inform park management?

Rocky Mountain NP provides a unique research site given that much of the park is now categorized as U.S. wilderness. Recording sounds of this unique park and wilderness region allows undergraduate research assistants a hands-on opportunity to create baseline acoustic files while effectively working as naturalists in their own backyard. These materials will serve as "sound libraries" for how a park should sound with or without anthropogenic noises.

Key words: *citizen science, millennial generation, geography, soundscape*

Hormones, Pharmaceuticals, Pesticides, and other Contaminants of Emerging Concern in Water, Sediment, and Fish from Rocky Mountain National Park, Colorado 2012-2013

William **Battaglin** (U.S. Geological Survey Colorado Water Science Center), Paul M. Bradley (USGS South Carolina Water Science Center), Luke R. Iwanowicz (USGS Leetown Science Center), Edward Furlong (USGS National Water Quality Laboratory), William Foreman (USGS National Water Quality Laboratory), and Michelle Hladik (USGS Sacramento Water Science Center). Corresponding author: wbattagl@usgs.gov

Hormones, pharmaceuticals, pesticides, and other contaminants of emerging concern (CECs) are commonly detected in surface water and bed sediment in urban and suburban areas due to the proximity and/or intensity of their use or their association with wastewater discharges and urban runoff. In 2008, National Park Service (NPS) issued a report that called for research "…to address the source and transport of these compounds into relatively pristine and sensitive aquatic ecosystems." Currently, the U.S. Geological Survey partners with NPS to investigate the sources, fate, transport, and persistence of CECs in NPS locations across the Nation.

In Rocky Mountain National Park, 67 water, 57 sediment, 63 fish, and 10 frog samples were collected from 20 streams or ponds in 2012-2013. Water samples were analyzed for 3 nutrients, 6 major ions, total estrogenic activity, 19 hormonally active compounds, 110 pharmaceutical indicator compounds, and 69 wastewater indicator compounds. Sediment samples were analyzed for 19 hormonally active compounds and 57 wastewater indicator compounds. All fish were bled for serum vitellogenin samples and had livers and gonads removed for histology. CECs were detected in water and sediment from both remote and more accessible locations in the park. Some detected compounds, such as carbaryl, 17-α-estradiol, celecoxib, and oxycodone, are attributable to direct human input, whereas others, such as camphor, estrone, 3-beta-coprostanol, and p-cresol, may have local natural sources such as wildlife or pine needles. Elevated vitellogenin (> 1 milligram per milliliter) was observed in 4 of 37 male trout tested and may be evidence of exposure to hormonally active compounds. Water from several of the remote pond sites showed evidence of estrogenic activity. The results indicate that even in remote locations, wildlife can be exposed to CECs in water and sediment, some of which are known or suspected endocrine disrupting compounds.

1. Honor the past: Provide a brief historical context for your work.

Rocky Mountain National Park has a 10,000 year history of human occupation and a nearly 100 year history of recreational visitation. Working ranches and dude ranches once occupied parts of the Park and visitors came by foot or horse. Now millions visit each year, largely coming by car but some still by foot or horse. Increasing visitation requires park managers to provide infrastructure needed to handle the "by products" of those visitors. This study examines the inputs of hormones, pharmaceuticals, pesticides, and other contaminants of emerging concern (CECs) to Park waters and attempts to determine the sources of those contaminants.

2. Celebrate the present: How is your work relevant to park visitors?

Some CECs likely arrive with dust and rain from distant locations and others originate from natural sources within the Park, but many are by products of visitation. The results from this study can be used to educate Park visitors on impacts of their activities while in the Park relative to other sources of CECs.

3. Inspire the future: How might your work inform park management?

Understanding the occurrence and sources of CECs and their persistence will help Park managers understand the magnitude of the problem and provide information that could help them determine if modifications to existing practices are needed to better protect the Parks water and wildlife resources.

Key words: *hormones, pharmaceuticals, pesticides, endocrine disrupting compounds, water, sediment, tissue*

Bird Migration Research at Rocky Mountain National Park

Jason **Beason** (Rocky Mountain Bird Observatory). Corresponding author: jason.beason@rmbo.org

The Rocky Mountain Bird Observatory and the National Park Service initiated projects to investigate the migration patterns of Osprey (*Pandion haliaetus*), Swainson's Thrush *(Catharus ustulatus*), and Western Tanager (*Piranga ludoviciana*) at Rocky Mountain NP. The goal of this research was to demonstrate migratory connectivity between Rocky Mountan NP and national parks and protected areas in southwestern United States, Mexico, Central America, or South America. Field work in 2012 resulted in ten Western Tanagers being captured and out-fitted with light-level geolocators. In 2013, four tagged tanagers returned to the same territories occupied in 2012 and two geolocators were recovered. Southeast New Mexico and western Texas were identified as stopover locations and wintering areas were southern Mexico and Guatemala for the tanagers. Also in 2013, two Ospreys were out-fitted with satellite tracking devices and tracked to Mexico and one light-level geolocators was deployed on a Swainson's Thrush. The thrush was recaptured in 2014 and preliminary maps indicate the thrush may have spent the winter in South America. The information obtained from this research represents the only complete documentation of a Western Tanager migration throughout its range and may be representative of the population occupying the southern Rocky Mountain region. The migration research conducted on Osprey and Swainson's Thrush at Rocky Mountain NP is unique to Colorado and reveals new information about the migration patterns of these species for the southern Rocky Mountain region. All birds tracked as a part of this research spent time near or in protected areas or national parks south of Rocky Mountain NP confirming the importance of these lands to migratory birds.

1. Honor the past: Provide a brief historical context for your work.

Rocky Mountain National Park is a designated Global Important Bird area and over 280 species of birds have been documented in the area. Conserving biological diversity is of interest to the National Park Service and in order to do so research must be conducted to gain a better understanding of the natural history of a species. Original research on bird migration involved banding and hoping that the birds would later be recaptured at another banding site thereby revealing new information about seasonal movements. However, the likelihood of recapturing the same bird at another location is low making it desirable for new methods to learn about bird migration.

2. Celebrate the present: How is your work relevant to park visitors?

Many visitors to Rocky Mountain NP come to experience wildlife and birds are an important component of the wildlife resource that attracts visitors to the park. Whether the experience involves seeing a hummingbird foraging at a wildflower, capturing a glimpse of a hawk soaring on a thermal, or watching a woodpecker search for beetles in the bark of a tree, birds add something special to everyone's experience of being in nature. Making certain that bird populations remain healthy so future park visitors can enjoy them is a goal of the migration research taking place at Rocky Mountain NP.

3. Inspire the future: How might your work inform park management?

Recent advances in technology enable researchers to gain valuable information about the migration patterns of birds immediately using satellite technology or after a complete migration has taken place using archival light-level geolocators. These tools give researchers the ability to track birds to their wintering areas and also reveal information about migratory pathways. Information gained is important and necessary for effective full-cycle bird conservation and demonstrates how land managers at other national parks or anywhere in the United States or in other countries must work together to make certain bird populations remain stable.

Key words: *birds, migration, biological diversity, conservation*

Mercury at Rocky Mountain National Park: Why we should care.

Katie **Bobowski** (Estes Park Options School), Jon Anderson (Eagle Rock School), Ben Baldwin (Rocky Mountain National Park), Otto Engel (Estes Park Options School), and Amos Westley (Estes Park Options School). Corresponding author: Katie.bobowski@yahoo.com

Mercury is a heavy metal which, in its methylated form, persists in the environment for a very long time. It is a concern because research has shown that methyl mercury can be a threat to the health of people and wildlife in many areas that are not obviously polluted. Recent local participation of Rocky Mountain National Park in a national mercury study prompted our interest in this topic. Preliminary data from dragonfly larvae samples suggest mercury at Rocky Mountain National Park varies greatly but may exceed wildlife health thresholds in some locations. We reviewed the literature as well as interviewed a Rocky Mountain National Park employee to determine the relevance of this heavy metal to the Rocky Mountain National Park ecosystem and visitors to the park. We will report our findings, identify areas of concern and suggest the environmental history that let to situation. Finally we propose a testable hypothesis for future investigation.

1. Honor the past: Provide a brief historical context for your work.

Methylmercury poisonings were described as early as the late 1800's but it was not until the last century that we began to understand the environmental impact of human caused Hg emissions.

2. Celebrate the present: How is your work relevant to park visitors?

Many visitors are unaware that even protected areas, like a national park, receive Hg from atmospheric deposition. In addition they may be unaware how far atmospheric mercury can travel and of the increasing evidence that Hg concentrations are increasing in protected areas. There are immediate potential health risks with increased levels in fish.

3. Inspire the future: How might your work inform park management?

Data from the dragon fly larvae mercury study can help park management educate the visiting public about mercury, its effect on the environment and how sources, even distant from the park can have long lived negative effects.

Key words: *dragonfly larvae, methyl mercury*

Citizen Science at RMNP: A Teenager's Perspective

Ashley **Bobowski** (Estes Park HS Student), Katie Bobowski (Estes Park Options School), Ben Baldwin (Rocky Mountain National Park), and Jon Anderson (Eagle Rock School). Corresponding author: Katie.bobowski@yahoo.com

In 2013 I participated in a study at Rocky Mountain National Park (RMNP) that looked at mercury concentration in dragonfly larvae. Mercury is a contaminant of concern and dragonfly larvae are thought to be an effective biosentinel of the persistence of the heavy metal in the ecosystem. The methods we used were standard protocols developed by U.S. Geological Survey, University of Maine, Schoodic Institute, and the National Park Service, most recently revised in April 2014. Although my participation was in RMNP, it is part of a national study. As a 13 year old, this was my first time participating as a citizen scientist. I will describe my experience and share my observations of what worked well as what may be improved upon to better engage students my age. In addition, I will present reflections from other student citizen scientists. A focus of my observations will be to offer ways to use opportunities like this to improve science literacy.

1. Honor the past: Provide a brief historical context for your work.

Rocky Mountain National Park has likely been an area where mercury has been deposited for decades and not well understood.

2. Celebrate the present: How is your work relevant to park visitors?

We believe that visitors are not aware that mercury is in the environment and that it may affect the ecosystem.

3. Inspire the future: How might your work inform park management?

Learning how mercury effects ecosystems the park management may be able to better manage the park.

Key words: *dragonfly larvae, citizen science, biosentinel, student, mercury*

Challenges in obtaining quality atmospheric deposition samples in the Loch Vale watershed, Rocky Mountain National Park, CO, USA

Daniel **Bowker**, (Colorado State University), Jill Baron (United States Geological Survey, Fort Collins Science Center, and Natural Resource Ecology Laboratory, Colorado State University), Greg Wetherbee (United States Geological Survey, Denver Federal Center), and Mark Rhodes (National Atmospheric Deposition Program, Illinois State Water Survey).
Corresponding author: daniel.bowker@colostate.edu

The Loch Vale watershed on the east side of the continental divide in Rocky Mountain National Park (RMNP) contains a highly important National Atmospheric Deposition Program (NADP) site used in monitoring of nitrogen deposition. This site, referred to as CO98 within the NADP, is the official monitoring station for the Rocky Mountain National Park Initiative Nitrogen Deposition Reduction Contingency Plan. This plan enables the state of Colorado to regulate nitrogen air pollution in order to bring air quality within the park into compliance with the plan's deposition reduction goals, if these goals are not met through voluntary action. The site is located on a granite knob at 10,400 feet in the subalpine basin near the Loch, and is exposed to the extremes of high altitude mountain weather, including heavy snows and high winds. The monitoring equipment at the site is powered by large battery banks which are recharged by solar panels. The small window of direct sunlight available to keep the batteries charged during the winter months means that ensuring adequate site power to properly run the monitoring station is a constant challenge. In order to check the quality of deposition data obtained at the site, a co-located site referred to as CO89 was installed in September 2009 five meters away from CO98, and removed in September 2014. While the data from the two sites were in close agreement for much of this period, diverging results from weekly precipitation sample analysis were noticed beginning in February 2014. This poster documents the process to uncover the reasons for these diverging results, and the fixes that were applied to bring the chemistry of the two sites back in line. After a series of repairs in the summer of 2014, analysis indicated that CO98 was indeed again returning quality data.

1. Honor the past: Provide a brief historical context for your work.

Though visitors to RMNP may believe that the park is untouched by what goes on outside its boundaries, our long term research project has shown this not to be the case. Power plants, animal feedlots, and automobiles along the Front Range emit compounds that travel into the park during upslope storm events, and these pollutants are deposited in the high elevations of the park, causing a cascade of ecological change. Having this long term record is important, as it documents that as emissions are reduced in the populated areas of Colorado, the benefits are felt in our parks and wildlands.

2. Celebrate the present: How is your work relevant to park visitors?

Maintaining the health and integrity of our national parks is a value that most Americans hold, and explaining to visitors how this is done is an essential part of the process. Nobody hikes above treeline to see alpine lakes choked with algae, or to wonder where the fish went in the streams. Visitors should be informed about the challenges of park management, and must see that management does not always mean just leaving someplace alone. Further, disclosure of the particulars of long term ecological monitoring and its challenges is vital to garnering the public support necessary to fund this work.

3. Inspire the future: How might your work inform park management?

Park managers directly benefit from our long term record of the ecology of the Loch Vale watershed. Our work gives managers the data they need to make informed decisions about how to best maintain the ecological functions of this wilderness park. Full documentation of the data collection process is significant to managers, as they need assurance that the data they use in modeling and planning are correct and defensible.

Key words: *Atmospheric deposition, nitrogen, Loch Vale, NADP, quality assurance*

Bear Lake Road Trailhead Visitors of Rocky Mountain National Park, USA

Kelly **Bricker** (HDR, Inc.). Corresponding author: Kelly.bricker@health.utah.edu

Rocky Mountain National Park is visited by over 3 million visitors per year. High and concentrated levels of visitor use within the park may negatively affect the quality of the visitor experience through crowding and traffic congestion. Typically, crowding is a social impact measured using quantitative methods and is based on normative theory (Jackson, 1965). Therefore, because of the need to manage for increasingly crowded areas, this study addressed areas that could potentially be added to an alternate transit system, relieving congestion on Bear Lake Road. In the context of crowding, normative theory states that each person has a threshold for the number of people they judge acceptable to see in a given circumstance. If that threshold is exceeded that person will feel some level of crowding (Vaske & Shelby, 2008). We employed the use of photographs to measure perceived conditions and as a method to estimate crowding conditions (Manning, 2003; Manning, 2007; Manning et al., 2002).This study was part of a broader study aimed to reduce crowding and congestion in the Bear Lake Road Corridor.

The purpose of this study was to understand visitor use patterns, preferences for social and natural resource conditions and potential management actions at five locations within the park: Lumpy Ridge Trailhead, Alluvial Fan, Deer Ridge, Hidden Valley and Sprague Lake areas. Visitors were approached at the completion of their visit, after having the opportunity to experience the trail location. The overall survey effort resulted in 960 completed surveys. This session will provide key results including, including:

- Socio-demographics of day users to the trailhead areas located Bear Lake Road;
- Visitor's use of park information;
- Impressions of crowding and the number of people at one time;
- Visitors impressions of transit features and options within the park; and,
- Recommendations and proposed management strategies moving forward.

1. Honor the past: Provide a brief historical context for your work.

ROMO was one of the first national parks to adopt alternative transportation solutions, initiating a shuttle bus route in the Bear Lake Road corridor in 1978. The system continues to operate during the peak visitor season and service has been increased over time to meet a growing visitor demand. The most recent change was the implementation of the Hiker Shuttle in 2006, which provides service between Estes Park and the Bear Lake Road Park and Ride Lot. System ridership has more than doubled since 2000, rising from approximately 156,000 riders annually in 2000 to more than 330,000 in 2013.

2. Celebrate the present: How is your work relevant to park visitors?

In order to understand whether the implementation of various management strategies are working, it is important to have a baseline understanding of the visitors behavior and preferences, to provide an understanding of the impacts (positive and/or negative) to the visitor experience. Because a park's transportation system, including roadways, transit, and trails, can greatly influence a visitor's experience, potentially in a negative way if the visitor experiences unacceptable levels of congestion. Potential modifications to the existing park shuttle system will provide visitors access to less crowded destinations outside the Bear Lake Road corridor and better integrated with the Town of Estes Park's existing shuttle system but may change the visitor experience over time at locations which have typically not had access to this system.

3. Inspire the future: How might your work inform park management?

The results of this study provide managers with a baseline understanding of the variation in 5 park locations, preferences by visitors and how they are utilizing and accessing park information. Project recommendations will provide park management with a baseline understanding of visitors to these locations in preparation for changes to the corridor and monitoring over time.

Key words: *visitor experience, transportation, congestion, perceived crowding*.

Rocky Mountain National Park and Santa Elena Cloud Forest Reserve Student scientific and cultural exchange.

Nicole **Brown** (St. Vrain Valley School District) and Melinda Merrill (Estes Institute). Corresponding author: brown_nicole@svvsd.org

A long standing Memorandum of Agreement has been established between Rocky Mountain NP (RMNP) and the Santa Elena Cloud Forest Reserve (SER) in Monteverde, Costa Rica making these park Sister Parks under the Sister Cities program. This agreement allows both parks to host an exchange of scientific research and student researchers. In the summer of 2014, six high school students from St. Vrain Valley School District and Estes Park High School embarked on this exchange. This exchange was supported by RMNP, SER, the Estes Institute, and Sister Cities and Birds without Borders.

While there, the Colorado student conducted research with SER staff and students from the Santa Elena community high school, who serve as stewards and researchers in the park. Many of these students also traveled to RMNP earlier in the summer of 2014 as part of the exchange. The research conducted utilized protocols used by both RMNP and SER researchers and included trap camera placement and monitoring, bird counts, macroinvertebrate studies, tree canopy investigations, insect biodiversity surveys and biological corridor monitoring. Therefore, both sets of students were able to conduct these protocols at RMNP and at SER.

While there, SER also brought in many presenters to discuss the issue and solutions percolating in the park and Costa Rica such as biological road crossings, road kill management and taxidermy, and biological corridor setup and monitoring. The Colorado students were also exposed to a cultural exchange. The staff and students of SER hosted us for dinners, weekend activities, and parties with their friends and families. The video presented was the culmination of the Colorado students' experiences with both the scientific and cultural aspects of our trip.

1. Honor the past: Provide a brief historical context for your work.

Both SER in Monteverde, Costa Rica and RMNP in Estes Park, Colorado lie near the continental divide. Therefore, they share many geologic and climatic patterns in common. Not only do they share common features, but they actually share individuals. There are many birds that migrate between the two parks. For centuries, these parks have shared species in common, perhaps without even knowing it.

2. Celebrate the present: How is your work relevant to park visitors?

Because of this shared experience and shared wildlife, the parks have embarked on a research and data share as well. They have worked to create this scientific/cultural student exchange program as well. I believe that this will benefit park visitors by strengthening community and support for RMNP. Not only does the park's existence and research matter to those that live nearby and visit from the US, but it supports those living around the world. We are able to help visitors see that although we, as humans, use borders, the wildlife that utilize the park do not, so it is important to work on conservation and park principles here as well as elsewhere around the world. By incorporating students, we are also inspiring the park stewards of tomorrow.

3. Inspire the future: How might your work inform park management?

Because studies on climate, birds, macroinvertebrate health, and water quality are shared between the two parks, park management can get a full picture of what is happening along the entire migration corridor of many birds. Together, with SER research and staff, RMNP officials are able to assess climate change patterns along the whole continental divide corridor and not just within the confines of the park. By incorporating a youth exchange portion to this agreement, park officials can inspire students to volunteer and perhaps work with the park to collect data in the future and continue the work started.

Key words: *RMNP, Santa Elena Cloud Forest, student, exchange*

Application of mouse models to investigate chronic wasting disease.

Jeffrey R. **Christiansen** (Prion Research Center, Colorado State University), Sehun Kim (Prion Research Center, Colorado State University), Elizabeth Wheeler (National Park Service Wildlife Health Branch), Jenny Powers(National Park Service Wildlife Health Branch), and Glenn C. Telling (Prion Research Center, Colorado State University). Corresponding author: Jeffrey.christiansen@colostate.edu

Chronic wasting disease (CWD) is a transmissible spongiform encephalopathy of both wild and captive cervids, (deer, elk and moose), in the Rocky Mountain region. It is a fatal disease with no current means of prevention or treatment. Our ultimate research goals are to develop management, prevention, and or treatment methods to limit the spread of CWD. To achieve our goals, we are investigating the mechanisms of disease transmission in a novel mouse model of CWD. Our new models express elk prion protein at levels comparable to those measured in elk tissue samples collected in RMNP. Increased levels of prion protein in peripheral tissues over previous mouse models allowed us to investigate various routes of inoculation. In an attempt to mimic natural transmission, intraperitoneal and oral inoculations, as well as co-housing experiments were performed. Our results indicate all three routes of transmission efficiently transmit disease. These studies establish the utility of our model system in assessing the time course of peripheral pathogenesis of chronic wasting disease and provide a useful model for investigating CWD transmission characteristics in the future.

1. Honor the past: Provide a brief historical context for your work.

Conservation efforts have long played important roles in protecting cervids in Rocky Mountain National Park. Mule deer populations benefited greatly from hunting bans even before the dedication of the park. Elk have made a remarkable recovery in the past 100 years since their reintroduction into the Estes Valley. Moose have also thrived within the park since their introduction into Northern Colorado in 1979. Chronic wasting disease is a non-native and recently emerged disease of members of the deer family. To maintain healthy populations, continued monitoring, disease research and implementation of management plans informed by science is required.

2. Celebrate the present: How is your work relevant to park visitors?

Thousands of visitors come to Rocky Mountain National Park every year in hopes of seeing wildlife both large and small. Members of the deer family are the most common large animals to be observed by many visitors. Future conservation efforts depend on the ability of the public to be able to enjoy a healthy population of these animals in their natural environment.

3. Inspire the future: How might your work inform park management?

Disease surveillance amongst the deer and elk herd is critical for making management decisions as well as providing a wealth of information on this newly emerging disease. Our research compliments information garnered from the natural hosts with data from a controlled laboratory setting. Specifically we can study the route and time-course of disease transmission. This information is critical for understanding earliest time point of dependable diagnosis and the kinetics of disease shedding.

Key words: *elk, wildlife disease*

Alpine moist meadow response to regional gradients of nitrogen deposition in the Rocky Mountains

Amber C. **Churchill** (University of Colorado), Matthew J. Ribarich (University of Colorado), and William D. Bowman (University of Colorado). corresponding author: amber.churchill@colorado.edu

Human alteration of the nitrogen (N) cycle has resulted in a drastic change in availability of biologically active N. Alpine ecosystems are particularly susceptible to increased inputs of N, as higher elevations receive high precipitation and therefore high rates of N input. The objective of our study was to examine effects of ambient N deposition in alpine moist meadow communities, and determine whether this gradient produces measurable responses of community and ecosystem processes associated with N cycling. Ambient levels of N deposition in many federally protected lands in Colorado are approaching, or have exceeded, the current estimated critical loads of N for changes in plant species composition, and we therefore selected sites located on federally protected lands receiving levels of N deposition along a gradient.

Our results show that sites receiving higher levels of N deposition have more indication of crossing ecosystem thresholds. Ecosystem responses such as soil water concentrations of nitrate, soil N availability are higher in areas receiving higher ambient levels of N deposition. The order of our sites receiving N inputs includes Arapaho National Forest (NF), Niwot Ridge Long Term Ecological Research site (Niwot), Rocky Mountain National Park (ROMO), Fraser Experimental Forest (Fraser), and Shoshone NF. Soil pH levels from each of these sites shows that Shoshone had the highest pH, followed by Fraser, Niwot, Arapaho and ROMO. Soil cation exchange capacity followed this exact pattern, with the highest buffering capacity in Shoshone and the lowest in ROMO. These findings suggest that increased N deposition, in these areas, is promoting nitrate mobility and subsequent leaching of base cations that producing lower soil pH. The plant community is also responding to N deposition, with differences in community composition among all sites observed, as well as differences in the relative abundance of moist meadow dominant plant species.

1. Honor the past: Provide a brief historical context for your work.

Some of the defining research examining effects of N deposition in the alpine was pioneered at Rocky Mountain National Park by using change in diatom communities in sediment cores. Since then, N addition experiments in alpine dry meadows have estimated threshold levels of N associated with changes in both community and ecosystem characteristics. At present, little work has examined whether these thresholds apply along gradients of ambient N deposition, and our work extends those analyses into moist meadow communities in numerous locations to compare the relative effects of N, climate, and other site specific factors on controlling ecosystem responses.

2. Celebrate the present: How is your work relevant to park visitors?

Trail Ridge Road, with its amazing vistas of the Rocky Mountain alpine, is one of the highlights for guests visiting Rocky Mountain National Park. For many guests this is their first opportunity to hike in the alpine, and enjoy the colorful and diverse flowers that cover this ecosystem. Understanding how the plants of the alpine, and the associated soil processes, are responding to nitrogen deposition will engage guests in protecting this potentially threatened ecosystem, and internalize how factors and events happening far beyond the borders of the Park may still drive changes in the remote protected areas of the West.

3. Inspire the future: How might your work inform park management?

The results from this study will help inform park management regarding how the alpine is fairing under current levels of N deposition in comparison with other alpine areas receiving both more or less N than Rocky Mountain National Park. We will also be able to understand the importance of climate in determining ecosystem responses, which is of concern under future scenarios of global change. Both of these implications will be especially important for Park contributions to policy decisions associated with the Clean Air Act and projecting how the alpine of the Park will continue under increasing/continuing rates of N deposition.

Key words: *alpine, nitrogen deposition, ecosystem responses*

Plains to the Park: integrating STEM initiatives into national parks

Ben Baldwin (Rocky Mountain National Park), Melinda Merrill (Estes Institute), Dan **Cribby** and David Kline (Westview Middle School). Corresponding author: cribby_dan@svvsd.org

Plains to the Park is a park-based STEM (Science, Technology, Engineering, Mathematics) experience hosted by Westview Middle School in partnership with the Continental Divide Research and Learning Center (CDRLC) of Rocky Mountain NP and the Estes Institute. In summer 2014, students, teachers and park staff participated in a two week STEM Academy at Westview Middle School and within Rocky Mountain NP. Students and teachers worked with CDRLC staff and volunteers to learn scientific methods and collect data in Horseshoe Park to answer questions relevant to current park management.

For two weeks in July, 22 middle school citizen scientists used standardized protocols as they conducted research on migratory birds, willow habitat, wildlife populations, and mountain lions. Students learned scientific field skills and gained experience in conducting basic point counts, vegetation and wildlife transects, and using GPS units, trail cameras, and field guides. In addition to citizen scientist crews, students participated in a film course over the summer to document and produce a video about their citizen science experience in the park.

1. Honor the past: Provide a brief historical context for your work.

For over 30 years, Rocky Mountain NP has provided K-12 students hands-on educational experiences through the Heart of the Rockies Programs. These environmental education programs are linked to Colorado standards and students can experience activities such as snow shoeing, building beaver lodges, and monitoring elk exclosures. The CDRLC has recently initiated a science literacy program that complements the Heart of the Rockies. The CDRLC efforts focus on teaching smaller groups of students the scientific process. Students engage in hands-on activities at the park to help them develop questions, follow established protocols, and participate in scientific data collection.

2. Celebrate the present: How is your work relevant to park visitors?

Plains to the Park helps engage youth in discovering the park and science at an important age. For students that connect through environmental education, this program is the next step towards deeper connections and stewardship. These students as visitors on their public lands, see interactions between science and stewardship first hand. This program provides a model of engagement for citizen scientists of all ages fostering a next generation of informed park stewards that will continue to protect these public lands.

3. Inspire the future: How might your work inform park management?

As a pilot program, the students learned about and collected data related to several important issues. Mountain lions are a keystone predator in the park and elusive, the camera traps will add to our understanding of where and when lions are active. The student efforts related to migratory birds complements park efforts to understand connections with sister parks in Costa Rica and investigate spatial and temporal scales. Overall, this program brings youth to the park which provides unique insights on how they connect to the park, use technology to engage and share that message with others through social media.

Key words: *youth engagement, mountain lions, song birds, camera traps, STEM*

Managing Cheatgrass with Imazapic in Rocky Mountain National Park: Lessons learned from a six year study

Christopher **Davis** (Department of Bioagricultural Sciences and Pest Management Colorado State University), Cynthia S. Brown (Department of Bioagricultural Sciences and Pest ManagementColorado State University), and Scott Esser (Rocky Mountain National Park). Corresponding author: cjd2@rams.colostate.edu

Cheatgrass (*Bromus tectorum* L.), an invasive Eurasian winter annual grass that competes with native species and alters fire regimes, has invaded much of the Western United States in the last century and, more recently, montane and subalpine ecosystems of Rocky Mountain National Park (RMNP). Control of this invasive species is a priority in RMNP. The purpose of this study was to determine the effectiveness of imazapic for cheatgrass control and its effects on non-target native species. In 2008, permanent monitoring plots were established in imazapic treatment sites in RMNP, with one reference and one imazapic treatment plot at each site. Imazapic (23.6% a.i.) was selectively applied to cheatgrass for three consecutive years, and application to native species was avoided. Plant community data were collected for six consecutive years, before, during, and after treatment. Plant species and functional group cover were estimated using modified Daubenmire cover-classes, and analyses of species cover, richness, and diversity were performed using a repeated measures analysis of variance model. Cheatgrass was reduced more than fivefold to approximately 5% absolute cover between 2008 and 2013 (ANOVA F-test, time and treatment interaction, P=0.04) in treatment plots. There was no change in absolute cover of native grasses, shrubs, or forbs in treatment plots, and native species richness and diversity did not change in treatment plots. Bare ground was greater in treatment plots but did not change significantly over time in response to imazapic treatment. Although cheatgrass cover was reduced following imazapic treatment, cover of native species did not increase. These results suggest that selectively treating cheatgrass with imazapic effectively controls cheatgrass while avoiding damage to native plant species; however post-treatment revegetation may be needed for full plant community recovery.

1. Honor the past: Provide a brief historical context for your work.

Unlike some invasive plant species in RMNP, cheatgrass is a relative newcomer, becoming more abundant in the park beginning in the 1980's. In recent decades it has become a common nuisance on roadsides and a variety of other commonly disturbed upland habitats, and has spread to some high-elevation sites in the park.

2. Celebrate the present: How is your work relevant to park visitors?

Cheatgrass negatively impacts the biological integrity of the ecosystems it invades and degrades the aesthetic qualities of invaded sites. Cheatgrass competes strongly with native plant species by maturing early and depleting soil resources, potentially forming monoculture populations if left unmanaged. Cheatgrass is also fire-adapted, and can increase fire frequency, making recovery difficult for native species adapted to longer periods between fires.

3. Inspire the future: How might your work inform park management?

This study provides information that can be directly incorporated into adaptive management strategies to more effectively control cheatgrass infestations and encourage the recovery of native plant communities following management actions.

Key words: *Invasion, invasive plant, exotic species, weed control, species diversity*

The effects of introduced fish on invertebrates in lakes of Rocky Mountain National Park, USA

Thomas **Detmer** (University of Colorado), James McCutchan (University of Colorado), and William Lewis (University of Colorado). Corresponding author: Thomas.Detmer@colorado.edu

Historically, ~95% of larger lakes (> 3 m depth, > 2 ha area) in the western United States were fishless, currently only ~5% of these lakes are fishless because of stocking programs. Previous studies of the effects of fish introductions on western lakes at high elevation show that introduced fish reduce aquatic insect and zooplankton biomass per unit area by selective predation on large taxa. Because of this, introduced fish also reduce mean body size of invertebrates and alter community composition. Most studies on the effects of fish on invertebrates in high elevation lakes have focused on the middle portion of the growing season, and none have evaluated the effects of fish on production of both aquatic insects and zooplankton. In corroboration with similar studies, the present study shows that annually, lakes with fish in Rocky Mountain National Park have lower biomass per unit area and smaller body size than fishless lakes. Despite differences between lake categories in biomass, the present study shows no difference in production of aquatic insects or zooplankton between categories; the lakes are homeostatic with respect to secondary production despite biomass differences. Resilience of secondary production occurs because size selective predation by trout reduces invertebrate body size, which results in an increase in the production to biomass ratio; the turnover rate for aquatic insects and zooplankton is higher in lakes with fish because body size is smaller, compensating for the reduction in biomass. This study shows that despite great changes in the structure of lake food webs because of predation by trout, the flow of energy in lakes does not change as is shown by similar rates of invertebrate production and similar abundances of attached and unattached algae.

1. Honor the past: Provide a brief historical context for your work.

Most or possibly all of the lakes in Rocky Mountain National Park were historically fishless. Of 156 lakes and ponds in the park, ~90 have been stocked with trout and presently 48 hold reproducing populations of fish. Unlike the surrounding area, management practices within the park have resulted in more lakes remaining fishless or allowed to revert to their fishless status since the 1970s when stocking was reduced. This has resulted in a high density of morphologically similar lakes with and without fish from which the effects of fish, such as in the present study, can be evaluated.

2. Celebrate the present: How is your work relevant to park visitors?

The ripples from a trout eagerly consuming an adult mayfly in the reflection of majestic peaks on a glassy mountain lake provide the perfect wilderness experience for many who visit Rocky Mountain National Park. Although many visitors think about fish in the park, few think of where they came from and their role in lake, stream, and even terrestrial ecosystems, where the reduction in emerging insects can lead to a local reduction in birds. Understanding the effects of fish on different ecosystems could provide visitors with an increased understanding of the strong interdependencies among species in the park.

3. Inspire the future: How might your work inform park management?

Similar to other studies, the present study shows that trout greatly reduce in abundance and in some cases extirpate large aquatic insects and zooplankton causing a restructuring of lake food webs. The present study also shows, however, that aquatic insect and zooplankton production do not differ between lakes with and without trout and that algal abundance is not different between lake categories. This study provides managers with information regarding resiliency and susceptibility of lakes to fish driven changes.

Key words: *trout, aquatic invertebrates, zooplankton, lake food webs*

Rocky Mountain Conservancy – Conservation Corps and the Next Generation of Public Land Stewards

Geoff **Elliot** (Rocky Mountain Conservancy). Corresponding author: Geoff.elliot@rmconservancy.org

Since 2003, Rocky Mountain Conservancy has sponsored a conservation corps program working in Rocky Mountain National Park. Originally, the program supported seven college interns on one crew for eleven weeks during the summer months. Due to the success of the program and the increased need of agency partners, the Rocky Mountain Conservancy – Conservation Corps has grown to provide thirty-six youth (ages 18-23) with a summer-long internship. Over the course of this time, participants complete over 320 hours of conservation work in-the-field in both Rocky Mountain National Park and the surrounding USDA Forest Service (USFS) areas. The youth are divided into six crews; each crew has five members, and one leader.

For eleven weeks, the crews live and work together within the Arapaho-Roosevelt National Forests (ARNF) or Rocky Mountain National Park (RMNP). Over this time interns gain extensive experience and knowledge of the inner workings of USFS and NPS, while spending eight weeks in-the-field completing conservation projects with the land management agency. The field-time is supplemented with three weeks of educational programming to further connect the youth with the land they are living and working within. Educational programming includes Leave No Trace principles, backcountry basics, cultural history, geology, environmental ethics, natural history hikes, and career development.

Since its establishment, Rocky Mountain Conservancy – Conservation Corps has been successful in reaching out to 225 youth. By combining on-the-ground conservation experience with these experiential field classes, the Conservancy hopes to prepare the next generation of stewards to our public lands.

1. Honor the past: Provide a brief historical context for your work.

In honor of the Civilian Conservation Corps' impressive work on our nation's public lands and, more specifically, in Rocky Mountain National Park, Rocky Mountain Conservancy works to continue the CCC's legacy of service and youth empowerment through the work of the Conservation Corps. Throughout their season, all interns participate in at least one cultural history field class, to enhance their understanding of the historical significance of conservation work in our nation's history.

2. Celebrate the present: How is your work relevant to park visitors?

Rocky Mountain National Park's high visitation makes it one of the most visited National Parks in the United States. With this level of visitation, there is increased impact on the 355 miles of trail. Increased impact necessitates increased support to ensure trails are safe and sustainable for visitor use. This past year, Rocky Mountain Conservancy – Conservation Corps completed maintenance runs on nearly half of the park's trail system, which provided visitors with an enjoyable experience on the trail and allowed the NPS trail crews to focus their efforts on flood recovery projects in Rocky.

3. Inspire the future: How might your work inform park management?

It is the primary goal of the Rocky Mountain Conservancy – Conservation Corps to empower youth with job skills, career development resources, a conservation ethic, and a connection to our nation's public lands to create the next generation of stewards. In pursuit of this goal, Rocky Mountain Conservancy does not attempt to convert all youth to careers in natural resources, but rather connect young people from all works of life and all career paths to our public lands to create a network of public land stewards to help support the protection of public lands in the future.

Key words: *youth, conservation corps, next generation, stewardship*

Hummingbird Survey, 2003-2012, Rocky Mountain National Park

Tena **Engelman** (Rocky Mountain National Park, Volunteers-in-Parks), Fred Engelman (Rocky Mountain National Park, Volunteers-in-Parks), T. Luke George, PhD. (Colorado State University and U.S. Geological Survey) and Sara J. Oyler-McCance (U.S. Geological Survey). Corresponding Author: fcengelman@earthlinknet

The hummingbird survey was approved in 2003 as a volunteer Citizen-Science inventory and monitoring program to collect demographic information, identify timing of nesting and migration, determine species present, monitor nesting area fidelity and longevity, analyze and report results, and provide a well-documented record for future park use. We monitored hummingbird populations on the east and west sides of the Continental Divide. Hummingbirds were seasonally observed at nearly all elevations. Montane ecosystem valleys provide the preferred habitat.

Broad-tailed hummingbird (*Selasphorus platycercus*) survival rates varied considerably over the course of the survey with the baseline site averaging 0.53 for adult females (range of 0.42-0.62) and 0.43 for adult males (0.32-0.54). The factors affecting annual survival are not well understood. Initial analyses of annual broad-tailed survival using two regional climate parameters (El Nino Southern Oscillation and the North Atlantic Oscillation) that have been observed to affect other migratory bird species did not appear to be related. Relative nesting and fledging success varied with some drier years showing better results than years with greater precipitation and cooler temperatures.

We observed considerable fluctuation in annual numbers of transiting rufous hummingbirds (*Selasphorus rufus*) indicating variable nesting and fledging success in their northerly breeding areas. Numbers of hatch year (juvenile) rufous varied from a low of 1 hatch year to 24 adults (2004) to a high of 1 hatch year to 3 adults (2003). Two rufous hummingbirds that we banded in the park were encountered in British Columbia and Alberta provinces. Numbers of transiting calliope hummingbirds (*Stellula calliope*) were relatively small and varied from year to year. Calliope presence at capture sites was affected by natural nectar resource availability.

We cooperated with research initiatives in Canada and Mexico. The U.S. Geological Survey accomplished genetic analysis and published the first genetic data on the broad-tailed hummingbird.

1. Honor the Past: Provide a brief historical context for your work.

The park is designated as an Important Bird Area with over 260 species observed. Prior to initiation of the survey, park historical records of hummingbird species were informal and limited. Monitoring of birds in various habitats began in the 1990s and included Breeding Bird Surveys that noted seasonal presence of broad-tailed hummingbirds. Our survey collected detailed population information to expand park knowledge of both summer resident and migrating species.

2. Celebrate the Present: How is your work relevant to park visitors?

The seasonally present hummingbird species provide park visitors with excellent opportunities to observe these birds in their natural habitat. An appreciation of hummingbird life cycle, factors influencing survival, and the long migration distances traveled by the smallest birds in the park expand visitor understanding of the importance of suitable habitat and an appreciation of the role of hummingbirds as migratory pollinators.

3. Inspire the Future: How might your work inform park management?

The health and maintenance of suitable broad-tailed hummingbird courtship and nesting areas as well as availability of wildflower resources is essential to their continued seasonal presence in the park. Monitoring and control of ungulate populations will prevent overgrazing of wax currant, twinberry, and willow species that are important for hummingbirds and other animals.

Key words: *hummingbirds, bird populations, bird migration, habitat*

Upslope Air Pollution Episodes in Rocky Mountain National Park during the Front Range Air Pollution and Photochemistry Experiment (FRAPPÉ)

Ashley **Evanoski-Cole** (Colorado State University), Katie Benedict (Colorado State University), Tony Prenni (National Park Service), Amy Sullivan (Colorado State University), Yong Zhou (Colorado State University), Barkley Sive (National Park Service), Sara Callahan (Harold Washington College), Derek Day (National Park Service), Bret Schichtel (National Park Service), Emily Fischer (Colorado State Universiry), and Jeff Collett (Colorado State University). Corresponding author: evanoski@atmos.colostate.edu

Air pollution from the Front Range urban corridor can be transported during upslope wind conditions and impact Rocky Mountain National Park. Sources of this air pollution include urban areas, agriculture and the rapidly growing oil and gas industry. In conjunction with the Front Range Air Pollution and Photochemistry Experiment (FRAPPÉ), an intensive air quality measurement campaign was conducted in Rocky Mountain National Park in July through October, 2014. The measurement site was collocated with an established CASTNet and IMPROVE monitoring site. The goal of this study was to further our understanding the impacts of upslope wind events at the site in the national park.

Measurements of inorganic gases and aerosol, precipitation, volatile organic compounds (VOCs) and peroxyacetyl nitrate (PAN) were obtained. High time resolution measurements included hourly inorganic gas and particle measurements from a Monitor for Aerosol and Gases (MARGA) and additional gas measurements collected every minute of ammonia, carbon monoxide, nitrogen oxides (NO and NO_x), and total reactive nitrogen (NO_y). Additionally, daily measurements of inorganic gases and aerosol and precipitation samples were collected. The VOC and PAN measurements have not been collected previously at this site and provide unique information about the sources and chemical processing of the air sampled at the measurement site. Upslope events were identified by an increase of ammonia, ammonium sulfate and ammonium nitrate aerosol. The concentration of some VOC tracers of urban and oil and gas activity and ozone also increased during upslope events.

1. Honor the past: Provide a brief historical context for your work.

Previous studies conducted by Colorado State University and the National Park Service have determined substantial impact of air pollution from the Front Range in Rocky Mountain National Park. Upslope events have been studied for their importance in transporting unhealthy urban emissions, such as ozone, into the park. Additionally, nitrogen compounds from agricultural and urban sources can be deposited in the park and are damaging to sensitive ecosystems within the park.

2. Celebrate the present: How is your work relevant to park visitors?

Air pollution in the national park can affect negatively impact visibility and the health of ecosystems within the park. High concentrations of aerosol can degrade visibility making the scenic vistas within the park appear hazy to a visitor. Nitrogen deposition can have detrimental impacts on sensitive ecosystems, which can alter the plant and animal life viewed by visitors.

3. Inspire the future: How might your work inform park management?

With continued population growth and the increase of the oil and gas industry in the Front Range, air pollution will likely continue to impact the national park. Understanding the transport and composition of upslope air pollution episodes, particularly from the more recent contribution from the oil and gas industry, is essential for understanding how issues such as visibility and ecosystem health will change in the future.

Key words: *air quality, ammonia, aerosol, FRAPPÉ*

Nitrogen and Anion Behavior in Alpine Tundra Soil, Rocky Mountain National Park.

Andrew **Evans** (Metropolitan State University of Denver). Corresponding author:aevans24@msudenver.edu

Anthropogenic nitrogen deposition can potentially alter soil biogeochemistry in alpine tundra ecosystems by soil acidification, resulting in accelerated nutrient leaching, and reduced microbial and plant diversity. Several field studies have simulated various atmospheric nitrogen loading rates, and observed changes in above ground biomass, species diversity, and soil buffering capacity. To date, few studies have examined the biogeochemical behavior and transport of nitrogen in alpine tundra soil. The objective of this study was to evaluate nitrate transport in soil, and the chemical behavior of associated leached ionic species. To accomplish this, a soil leaching studying was conducted using both composite soil columns and intact soil cores, collected at Rocky Mountain National Park, CO, USA, elevation 3658 meters. Soil columns were leached in a temperature controlled environmental chamber.

Leachates were collected and analyzed for nitrogen and common soil anions. Leachate analysis indicated seasonal shifts in nitrogen composition within the soil solution. During spring melt-off ammonium was primarily leached from the soil, while nitrate was leached in soil during the end of the summer dry season. Nitrate concentrations > 30 mg/L were observed in the breakthrough pore volumes for the unsaturated soil columns. Elevated leachate concentrations for inorganic (SO_4^{2-}, F^-) and organic anions (acetate, oxalate) were observed for individual soil horizons. Fluctuations of approximately 2-3.5 pH units for individual soil horizons were observed and the anion transport order suggests possible complex anion exchange processes in the soil-wetting front. Changes in nitrogen and nutrient cycling within alpine tundra soils can result in fundamental changes in soil ecology.

1. Honor the past: Provide a brief historical context for your work.

Soil nutrient cycling and soil ecology have historically been overlooked, with emphasis being focused on aquatic and above ground ecosystems. As a result, our knowledge of alpine tundra soil in RMNP is derived primarily from soil surveys conducted in the Park, and baseline data with respect to soil nitrogen and nutrient availability is limited. Soil baseline nutrient values control plant community diversity and populations. Current research can provide baseline nutrient concentrations to assess future climatic changes. Soil research near Trail Ridge Road has been continuous for the past three years.

2. Celebrate the present: How is your work relevant to park visitors?

Alpine tundra ecosystems are sensitive environments that respond rapidly to environmental impacts, both natural and human. By correlating above ground vegetation to subsoil processes, Park visitors can gain a deeper appreciation of the interactions between soil processes and observed vegetation/animal life in an alpine tundra ecosystem.

3. Inspire the future: How might your work inform park management?

By assessing the current stored nitrogen levels and the processes controlling nitrogen cycling in soil, park management can better assess the impact of atmospheric nitrogen loading on alpine ecosystems. Atmospheric nitrogen loading has been shown to impact alpine stream quality, while the contribution from soil leaching has not yet been determined. By understanding nitrogen-loading trends in soils, management can better anticipate changes in plant communities, and shifts between dominant plant species.

Key words: *alpine tundra soil, nitrogen, nitrate, soil N loading, nutrients*

Biogeochemical Signatures of Alpine Glacial and Periglacial Features throughout the American West.

Timothy **Fegel** (Colorado State University), Jill Baron (United States Geological Survey, Colorado State University), Ed Hall (Colorado State University), Claudia Boot (Colorado State University), Andrew Fountain (Portland State University), and Gunnar Johnson (Portland State University). Corresponding author: tim.fegel@colostate.edu

Alpine glaciers in the American West are projected to be non-existent within the next 100 years. Better understanding of what the loss of these frozen masses will mean for mountain ecosystems is needed. Rock glaciers, which are heterogeneous periglacial masses of ice and lithic material that move through plastic deformation, are far more abundant than ice glaciers in the alpine regions of national parks in the western United States. However, there is little research comparing the biological and chemical inputs of rock glaciers relative to ice glaciers. In our comparative study of outflow chemistry and biology from 18 pairs of glaciers and rock glaciers across the Cascades, Sierra Nevada, and Rocky Mountains, we hypothesized that; 1. Physical and chemical bedrock weathering products will be greater from rock glaciers than ice glaciers, making more micronutrients available to the downstream freshwater ecosystem. 2. Differences in microbial communities between glaciers and rock glaciers may result in differential processing of reactive elements with the potential to affect the downstream ecosystem. 3. Dissolved organic matter (DOM) will be more microbially processed and recalcitrant than DOM from ice glaciers.

Results show significant differences in outflow chemistry between ice and rock glaciers. Although there was greater variability, rock glaciers had significantly higher temperatures, pH, silica, total dissolved nitrogen and metal ion content, and electrical conductivities than their respective study-paired ice glaciers. Ammonium levels were near or at detection limit for both types of features, however NO3- values varied between paired sites and appeared to be related to regional atmospheric depositional loads. While DOC values were low for both ice and rock glaciers, DOM structure, as observed through fluorescence measurements, varied between paired rock-ice glacier sites, and was suggestive of microbial sourcing in ice glaciers, while DOM in rock glaciers was representative of both microbial and terrestrially-derived sourcing.

1. Honor the past: Provide a brief historical context for your work.

Originally carved during the Pleistocene, glacial cirques form the crown of the mountain ranges of the American West. Once the origin points of ice sheets spanning millions of hectares, diminutive modern glaciers now filling the cirques act as fleeting historians, reminding visitors of the immense power of the cryosphere, at least for the time being. Our work examines how these melting ice bodies chemically affect the alpine headwater ecosystems they inhabit, and what eventual ice glacier loss will mean ecologically.

2. Celebrate the present: How is your work relevant to park visitors?

The Loch Vale Watershed may be the most visited alpine headwater system in the continental United States. Andrew's Glacier and Taylor Rock Glacier may also be some of the most viewed alpine glaciers in the western hemisphere. For many visitors, this may be the only glacier they step foot upon. A better understanding of how melting ice glaciers and rock glaciers are impacting the alpine environment could help park visitors understand the distal impacts of anthropogenic atmospheric deposition and climate change.

3. Inspire the future: How might your work inform park management?

The impacts of glacier and rock glacier meltwater to sensitive alpine ecosystems remain unknown. Understanding how climate change will alter the thermal regime and input of nutrients and minerals to sensitive alpine watersheds is necessary for park management to make informed decisions when working with legislature. For example, excessive dust deposition can enhance ice melting by orders of magnitude. Understanding how deposited compounds enter the alpine ecosystem through atmospheric deposition on ice can help us better quantify the effects of anthropogenic dust creation and propagation into mountainous National Parks.

Key words: *glaciers, climate change, biogeochemistry, microbial ecology*.

Decadal Trends in Fish Mercury Concentrations and Comparison to Health Criteria, Rocky Mountain National Park, USA

Colleen Flanagan Pritz (NPS Air Resources Division), Collin Eagles-Smith (USGS), James Willacker (USGS), Don Campbell (USGS), Alisa Mast (USGS), Dixon Landers (EPA), Mary Kay Watry (RMNP) and Chris **Kennedy** (USFWS).
Corresponding author: colleen_flanagan@nps.gov

Rocky Mountain National Park (RMNP), a protected area considered to be relatively pristine and removed from environmental contaminants, not only contains levels of mercury in some fish that exceed human and wildlife health thresholds, but is also experiencing increased concentrations of mercury in fish over time. We measured mercury (Hg) in a total of 579 fish collected 2003–2012 across 19 water bodies at RMNP. Across all sites and 5 species, fish Hg concentrations ranged from approximately 2.0 to 526 ng/g ww, with a mean of 75.1 ng/g ww. Within 17 distinct fish populations at 14 of the sites, the same fish species were sampled by separate studies to illuminate decadal differences in mercury concentrations. In three-fourths of the fish populations, intraspecific mercury levels increased 1.3-fold overtime. Factors contributing to this finding could include shifting food web dynamics, increased methylmercury production, and increased mercury deposition. Additionally, the most recent fish dataset (Eagles-Smith et al. 2014; n=385) was compared to a range of toxicity thresholds including fish (NOER; 200 ng/g ww in whole-body), avian (90 ng/g ww in whole-body), and human (300 ng/g ww in muscle tissue) health benchmarks. Concentrations varied by more than 6.5-fold between the sites with the lowest (Lake Haiyaha; 19.8 ng/g ww) and highest (Mirror Lake; 121.2 ng/g ww) average concentrations. Two percent of fish in the dataset exceeded the NOER, while 15 percent of fish exceeded the highly sensitive fish-eating bird health threshold. Three percent of fish exceeded the EPA human health criteria. Exposure to high levels of Hg in humans may cause damage to the brain, kidneys, and the developing fetus. In wildlife, elevated Hg levels can result in reduced foraging efficiency, survival, and reproductive success. Much of the mercury found in these mainly high elevation areas is likely the result of air pollution that travels to the park from outside park boundaries.

1. Honor the past: Provide a brief historical context for your work.

This study provides a snapshot of variation in fish mercury concentrations by resampling 17 water bodies that were first examined in 2003.

2. Celebrate the present: How is your work relevant to park visitors?

Many visitors enjoy sport fishing in the park's serenely mountainous lakes and streams. In addition to recreational enjoyment, fish also offer spiritual, cultural, and dietary benefits.

3. Inspire the future: How might your work inform park management?

The results of this work facilitate informed management decisions regarding site-specific reintroduction efforts and communication to visitors about potential health risks.

Key words: *fish, mercury, health, airborne pollutants, lakes, rivers, contaminants*

The Effects of Bark Beetle-Fire Disturbance Interactions on Post-Disturbance Forest Regeneration

Jean **Fleming** (Colorado State University) and Jason Sibold (Colorado State University). Corresponding author: jeanlf@rams.colostate.edu

When disturbances occur in forested ecosystems they create ecological legacies that can influence the size and severity of future disturbances. In addition, interacting disturbances can become compounded and affect post-disturbance regeneration. Compounded disturbances are concerning for forest management because they can lead to extreme changes in forested ecosystems including new species assemblages or alternative stable states. I completed research within Rocky Mountain National Park on the post-disturbance regeneration following two interacting disturbances, a bark beetle outbreak and a high-severity fire. The goal of my research was to identify the factors that influence post-fire seedling establishment, and to determine whether bark beetle-fire interactions had a compounded effect on subalpine forest regeneration. I evaluated seedling establishment at study sites within the Cow Creek fire that burned in 2010 in the northeast corner of the park. My results show that the amount of lodgepole pine, quaking aspen, and Engelmann spruce seedling regeneration was significantly greater in areas that had undergone recent bark beetle disturbance before the fire. These results are contrary to past research which indicates that compounded disturbances generally reduce or eliminate forest regeneration. My results suggest that the forests affected by the Cow Creek fire will regenerate to their pre-disturbance species assemblages. In addition my research improves the understanding of the many ways compounded disturbances can affect forest regeneration.

1. Honor the past: Provide a brief historical context for your work.

Disturbance interactions can affect forests over multiple centuries. In order to give context to my analysis my research includes a consideration of fire history and historical management practices within the national park. These historical events created ecological legacies that influenced both the recent bark beetle outbreak and the Cow Creek fire and affected the forest regeneration following those events.

2. Celebrate the present: How is your work relevant to park visitors?

Disturbance plays a vital role in maintaining the subalpine forest ecosystems that visitors enjoy with the park. However, compounded disturbances have the ability to cause changes to the ecosystems that visitors utilize. Without a clear understanding of how compounded disturbances affect forest seedling establishment, it is difficult to assess whether the parks forests will regenerate unaided following these compounded disturbances. My research increases the knowledge base on how forests regeneration responds to compounded disturbances and directly addresses what patterns of post-compounded-disturbance establishment are currently occurring within the park.

3. Inspire the future: How might your work inform park management?

Forest management following compounded disturbances can be difficult because of the unpredictable nature of post-compounded-disturbance regeneration. Cases in which compounded disturbances have pushed ecosystems into alternative stable states have created concern that compounded disturbances must be heavily managed in order for ecosystems to return to pre-disturbance species assemblages. My research shows that this is not always the case, and that compounded disturbances can stabilize forest regeneration. These discoveries should be considered in the future when management plans are created to manage forests that have undergone compounded disturbance.

Key words: *Compound disturbance, Disturbance, Bark beetle, Fire, Regeneration, Subalpine forest*

Forty-years of Change in Aspen Forests, Rocky Mountain National Park, USA

Scott B. **Franklin** (University of Northern Colorado), Mario Bretfeld (University of Wyoming) and Robert K. Peet (University of North Carolina at Chapel Hill). Corresponding author: scott.franklin@unco.edu

Forests dominated by aspen (*Populus tremuloides*) provide a variety of ecosystem services. In the Southern Rocky Mountain region, species richness, nutrient cycling and herbaceous biomass are generally higher under aspen than in conifer-dominated habitats, justifying their protection. Though confounded, several studies suggest aspen stands are decreasing in Colorado. The objective of this study was to assess changes in forest communities containing aspen over the past 40 years in the Colorado Front Range using a previously sampled plots (Robert K. Peet, 1972 -1973), and dendrochronological analysis to examine the response of aspen to the bark beetle epidemic. We hypothesized that (a) aspen basal area and density have decreased at the landscape scale, (b) understory species diversity changes mirror those of aspen overstory changes, and (c) aspen is responding positively to recent disturbances (fire and beetle outbreak).

Aspen were no longer present in 22 of 89 plots, and aspen density for small stems (< 2.5 cm diameter at breast height) had declined significantly overall, although larger stems had not changed significantly. The decrease was more pronounced at higher elevations and specific to aspen-dominated forests. A slight upslope shift was observed for most species, especially on north-east facing slopes, suggesting climate-related responses. Understory vegetation diversity significantly decreased at the landscape scale. Changes were most pronounced in the subalpine zone, specifically in *Pinus contorta* (lodgepole pine) dominated forests. Changes in diversity were significantly correlated to aspen stem density, and aspen showed a clear radial growth release in stands that were subject to excessive beetle-derived conifer mortality.

In conclusion, aspen were persistent in mixed forests and may be beneficiaries of the recent bark beetle epidemic but decreased and were subject to succession in previously aspen-dominated stands. Our results help develop optimum monitoring and management strategies aimed to sustain aspen in the forested mountains of Colorado.

1. Honor the past: Provide a brief historical context for your work.

Establishment of aspen in Colorado dates back centuries to millennia. While all other species regenerate through seeds, aspen regeneration is strictly from roots. How do these important forests maintain themselves on the landscape? Researchers have suggested since the 1940s that aspen stands were declining. More recently, the hastened loss of overstory trees due to Sudden Aspen Decline (SAD) suggests drought and resulting xylem cavitation as a factor. The unique data here provide a quantitative view of aspen dynamics over a period of 40 years in Front Range forests and potential reasons.

2. Celebrate the present: How is your work relevant to park visitors?

Throughout most of its western distribution, aspen forests exhibit higher decomposition rates, nutrient availability, and soil moisture, and harbor higher herbaceous biomass and species diversity in the understory compared to co-occurring coniferous forest. The unique ecosystem structure and function of aspen forests generally lead to greater animal diversity as well. Ecosystem services provided to humans include this diversity for recreation as well as clean water. Aspen forests in the fall provide a ‘modern gold rush’ of tourism and, for the above reasons, maintaining these forests is a high priority of land stewards.

3. Inspire the future: How might your work inform park management?

Aspen forests provide key habitat and structure for a variety of plants and animals. Maintaining these forests with changing climate (potentially more droughts and fires) and herbivores (negatively impact reproduction) in not clear. A better understanding of how aspen respond to these changes throughout the landscape, along with physiological mechanistic responses by these clonal organisms, will provide conservation scenarios that can be weighed for their efficacy and properly implemented.

Key words: *aspen, forest, climate change, vegetation dynamics, mountain*

Montane Forest Structure and Fire History, Colorado Front Range, USA

Ben **Gannon** (Colorado Forest Restoration Institute, Colorado State University), Michael Battaglia (USDA Forest Service, Rocky Mountain Research Station), Paula Fornwalt (USDA Forest Service, Rocky Mountain Research Station), Peter Brown (Rocky Mountain Tree Ring Research), Laurie Huckaby (USDA Forest Service, Rocky Mountain Research Station), Antony Cheng (Colorado Forest Restoration Institute, Colorado State University), and José Negrón (USDA Forest Service, Rocky Mountain Research Station). Corresponding author: benjaminmgannon@fs.fed.us

Recent large and uncharacteristically severe wildfires have caused concerns to be raised about the resilience of ponderosa pine-dominated montane forests of the Colorado Front Range. In response, managers are increasingly implementing landscape-scale ecological restoration projects, which include both structural restoration to recover natural stand conditions and landscape mosaics, and process restoration through increased use of prescribed and characteristic wildland fires. This restoration work is largely guided by science from other regions, especially the Southwest USA, and there is a clear need to improve our understanding of Front Range montane forest ecology to develop locally-relevant and ecologically-appropriate restoration guidance, given that significant differences in climate, topography, past and current land uses, and forest productivity exist between the regions. We describe a current project to develop models of historical patterns and processes using tree-ring based reconstructions that is intended to inform restoration efforts. This project, the Front Range Forest Reconstruction Network (FRFRNet), was designed to examine changes in forest conditions and fire regimes across spatial environmental gradients of the Front Range. FRFRNet consists of 179 0.5 ha plots with data collected on current and historical (ca. 1860) forest structure (density, basal area, size and age distributions), composition, stand spatial patterns, and fire regime (using fire history and establishment data). The network will provide site specific reference conditions as well as regional models to inform restoration work. It will also provide valuable data to test hypotheses about how forest conditions and fire interact over large spatial extents and long timespans. Preliminary results confirm expected trends, especially that historical forests were less dense than modern counterparts, but also demonstrate high landscape-to-regional scale diversity in forest structures and fire histories across the montane zone.

1. Honor the past: Provide a brief historical context for your work.

Forest restoration has been a hot topic in the Front Range since we began experiencing modern megafires in the 1990s. There has been heated debate about ecological restoration and specific methods of implementation in Front Range Montane Forests. This project provides a deep perspective on the historical range of variability in forest structures and fires prior to Euro-American settlement (ca. 1860) that will be used to better define ecological restoration goals and to design more effective management approaches.

2. Celebrate the present: How is your work relevant to park visitors?

The lower-elevation valleys and hillsides of RMNP are the highly visible gateway to the park. Management of these ponderosa-pine dominated forests and woodlands that allows for fire's natural role can provide excellent educational opportunities for park visitors travelling through these systems.

3. Inspire the future: How might your work inform park management?

Knowledge of the historical range of variability in forest structures and fire processes is instrumental for ecologically-based management of these systems. Forest conditions, both within the park and on adjacent public and private lands, affect wildfire risk, potential wildfire behavior, and resulting ecological and social responses to fire. Given the wilderness nature of Rocky Mountain NP, structural restoration will not be commonly employed, but the historical reconstructions produced by this project may be utilized as benchmarks against which change can be monitored in these systems and for planning and assessing the role of fire use as a management tool.

Key words: *montane forest, ponderosa pine, fire ecology, ecological restoration, dendrochronology*

Alpine Restoration of Alpine Ridge Trail in Rocky Mountain National Park

Michelle **Gibbons** (Rocky Mountain National Park) and Kevin Gaalaas (Rocky Mountain National Park). Corresponding author: michgibbons23@hotmail.com

The Alpine Ridge Trail is a high use scenic trail located next to the Alpine Visitor Center that ranges in elevations from 11,796 feet to 12,096 feet within a distance of one quarter of a mile. Over the course of time, the combination of high visitor use, variable weather, and steep grades of the trail caused significant deterioration to the trail and adjacent plant life that warranted restoration. Construction and restoration of the trail began in the summer of 2010 with the following objectives and goals in mind: create a more sustainable and safer trail, restore an abandoned section of trail with salvaged tundra that will mimic the adjacent area, restore disturbed areas trailside with salvaged tundra and propagated native alpine plants, and restore areas so they will be productive, stabilize the soil, and be resistant to invasive plants.

The complexities of restoring the site were many. Yards of topsoil required transport and distribution along the trail which increased the chances of introducing non-native species. Large quantities of tundra in proposed disturbance areas needed to be properly salvaged, planted, and/or stored in cold frames. Thousands of alpine plants propagated from native seed were also needed to supplement the salvage as the disturbance exceeded the final footprint of the new trail. With various divisions involved in different aspects of the overall project, interdivisional collaboration and cooperation proved to be critical in efficiently executing and completing the project.

The project was completed in 2014 and the restoration appears to be successful, thus far. Minimal plant death has been observed and small patches of non-native species have been manually controlled.

1. Honor the past: Provide a brief historical context for your work.

Dr. Beatrice Willard was an alpine ecologist who extensively studied human impacts on alpine vegetation. She monitored plots for nearly 40 years with results showing plant life could take 20 years to centuries to fully recover in impacted areas. With this in mind, it was important in the restoration of the Alpine Ridge Trail that effort be taken to salvage all tundra in proposed disturbed areas. By planting salvaged tundra and propagated alpine plants, species diversity and richness was preserved that could have taken centuries to achieve.

2. Celebrate the present: How is your work relevant to park visitors?

What is special about Rocky Mountain National Park is that approximately one third of the park is alpine tundra. Though small in comparison to the amount of tundra surrounding it, the restoration area of the Alpine Ridge Trail parallels one of the most popular trails that allow visitors to walk along this unique ecosystem. Restoring the site was important ecologically as well as preserving the visitor experience.

3. Inspire the future: How might your work inform park management?

With ongoing monitoring of the Alpine Ridge Trail site, park management can look at the results to inform them on how to approach future alpine restoration projects. Decisions can be made on the use of topsoil; it the topsoil necessary and is it worth the risk of introducing invasive species? Planting techniques of tundra and propagated plants may be adopted or altered depending on site conditions. With a precedent now set, future alpine projects will have data and observations to hopefully guide them towards more efficient and successful results.

Key words: *alpine, restoration, vegetation, trampling*

Reestablishment of Vegetation on Disturbed High Mountain Lakeshores Following Dam Removal, Rocky Mountain National Park, USA

Amy **Goodrich**, David Cooper, and Kristen Kaczynski (Colorado State University). Corresponding author: amy.goodrich@colostate.edu

Dam removal has entered the public spotlight in recent years, due to growing safety, economic, and environmental concerns related to dams. Removal is increasingly seen as a way to address not only the risks associated with aging and/or obsolete dams, but also as a tool for ecological restoration. In 1982, then-79-year-old Lawn Lake Dam in Rocky Mountain National Park (RMNP) failed, emptying nearly the entire reservoir pool in a matter of hours down Roaring River and into Fall River, resulting in three deaths, and extensive monetary damages and destruction of natural resources within the Park and adjacent town of Estes Park. The presence of three remaining "Significant Hazard"-classified dams within the Park, coupled with NPS-wide guidance stating that non-essential dams within the National Park System should be deactivated and removed, drove a policy decision to remove the three additional dams between 1988 and 1990. These dam removals returned their respective reservoirs to previous natural lake water levels, and re-exposed nearly 13 hectares of scoured shoreline, denuded of vegetation by approximately 80 years of inundation. Active revegetation efforts by the Park were limited to minimal planting at stream outlets, and the remaining disturbed areas were left to undergo passive restoration. In the years immediately following removal, limited revegetation data were gathered at a handful of plots established at the disturbed lakeshores. However, until the present, no published analyses of these short-term data were made available, and these lakeshores had not since been officially revisited for collection of subsequent data to examine longer-term vegetative effects. In 2014, vegetation surveys and soils collection were conducted in 142 plots at nine high mountain lakeshore sites, including the four previously-dammed lakes and five undisturbed reference lakes. Data are being analyzed to examine the long-term impacts of damming and dam removal on lakeshore vegetation communities, exploring relationships of this disturbance to current vegetative composition, cover by species, and richness, as well as identifying unique site characteristics.

1. Honor the past: Provide a brief historical context for your work.

At the time of these historic dam removals a quarter century ago, few dams had been intentionally removed nationwide, and so little had been studied about the ecological processes following dam removal. RMNP's pioneering leadership in this relatively-new field positioned the Park to serve as a flagship for the study of dam removal as a restoration tool, and one of few sites where the long-term effects of ongoing passive restoration processes can be observed today.

2. Celebrate the present: How is your work relevant to park visitors?

In opting to allow passive vegetative restoration, it was the intention of the NPS that these sites might serve to educate visitors, who could over the years observe the processes of vegetation recolonization and succession "in action." Though these previously-dammed lakes – all of which are currently popular hiking and camping destinations – have extensively revegetated, observant visitors can still see remnants of the lakes' raised water-level legacies in the form of visible lichen waterlines, historic shoreline contours, and unique vegetation communities. This study sheds light on current outcomes, and augments understanding of these processes ongoing in the Park.

3. Inspire the future: How might your work inform park management?

The decommissioning/dismantling and removal of dams is a growing practice, necessitated by the aging state of American dams and the shifting ecological values driving future decisions about their fates. As such, an understanding of the long-term ecological changes caused by dam removal is increasingly important. Nearly 25 years after dam removal, analysis of the existing vegetation at RMNP's disturbed lakeshores can provide a clearer understanding of the longer-term effects of damming and dam removal in high mountain ecosystems. This information will help to inform future dam removal decisions and high mountain restoration recommendations and practices throughout the NPS.

Key words: *dam removal, disturbance, high alpine, passive restoration, revegetation, reservoir*

The diatom (Bacillariophyta) genus *Nitzschia* Hassall in Rocky Mountain National Park

Sarah E. **Hamsher** , Joshua G. Stepanek & J. Patrick Kociolek (Department of Ecology and Evolutionary Biology and Museum of Natural History, University of Colorado). Corresponding author: patrick.kociolek@colorado.edu

Diatoms are used widely as indicators of environmental condition and change in aquatic ecosystems. One of the most commonly identified genera associated with environmental change is *Nitzschia* Hassall, a benthic diatom. While a few species of *Nitzschia* are known from unimpacted waters, most known species are considered indicators of elevated nutrient levels. As part of a survey of the diatoms of Rocky Mountain National Park, we were surprised to encounter a diversity of *Nitzschia* species in the samples. In this paper we describe the *Nitzschia* species present in samples taken during the summer 2014 sampling period, and specify the localities in which *Nitzschia* species are present, with a focus on those collections in which the relative abundance of this genus is highest. The number and autecology of species present suggest to us that some habitats in RMNP may contain high levels of organic nutrients, and these habitats are worthy of additional research.

1. Honor the past: Provide a brief historical context for your work.

This work combines sampling efforts from monitoring work and other collections to begin to inventory these important members of the base of the food chain in aquatic ecosystems. The focus on the genus *Nitzschia* is important. Only four species have been reported previously and no specimens have been illustrated from the Park. It is likely that previously undescribed species of this genus are present in Rocky Mountain N.P.

2. Celebrate the present: How is your work relevant to park visitors?

Nitzschia is a great example of how microbes can tell us a lot about ecosystem health.

3. Inspire the future: How might your work inform park management?

The genus *Nitzschia* has many species that are indicators of organic pollution. The widespread occurrence of the genus in many aquatic habitats in the Park, and in some cases with high relative abundances, may help identify impacted ecosystems and help focus remediation efforts.

Key words: *diatoms, aquatic ecosystems, new species, Nitzschia, organic pollution*

Effects of Large Woody Debris and Log Jams on Eastern Slope Rocky Mountain Trout Populations.

Adam **Herdrich** (Colorado State University, Colorado Cooperative Fish and Wildlife Research Unit), Dana Winkelman (U.S. Geological Survey, Colorado Cooperative Fish and Wildlife Research Unit), and David Walters (US Geological Survey, Fort Collins Science Center). Corresponding author: Adam.Herdrich@gmail.com

High elevation streams have been cleared of jam-forming large woody debris (LWD) through direct mechanisms, such as clear-cutting, snagging, and river clearing. LWD has also been reduced through indirect means, such as eradication of beavers. Our project examines how trout populations in high elevation streams along northern Colorado's Front Range are affected by LWD by comparing streams with high amounts of in-stream LWD to streams with medium and low amounts of LWD. We will focus on streams in Rocky Mountain National Park and summarize results from two field seasons examining trout densities in streams with varying amounts of LWD. Trout densities were generally highest in streams with large quantities of LWD and lowest in streams in which LWD was minimal or absent. Preliminary analyses of trout growth rates between two streams, one with low LWD and another with high LWD, indicate that growth is similar between these streams. We initially hypothesized that the population in the high elevation/high LWD stream would have lower growth based on a shorter growing season and higher trout densities. Similar growth rates between the streams suggest that resource availability may be responsible for controlling trout growth. Our data provide insight into the mechanisms controlling trout growth rates and can inform decisions regarding the management of trout fishery resources in Rocky Mountain National Park.

1. Honor the past: Provide a brief historical context for your work.

An important feature of Rocky Mountain National Park is the influence of historic timber clearing. Many areas in the park were cleared of riparian forests leading to a paucity of in-stream LWD and logjams that were historically present in these stream ecosystems. The loss of LWD affects both the aquatic and riparian food webs (presentations by Drs. Ellen Wohl's and Michael Venarsky). However, some high elevation streams that were not easily accessible still have intact riparian forests, allowing us to contrast and understand the effects of losing LWD.

2. Celebrate the present: How is your work relevant to park visitors?

Although difficult to access, the historically intact riparian forest in Rocky Mountain National Park can provide visitors an appreciation for the importance of maintaining functionally intact ecosystems. Our work demonstrates that fish densities are higher in old growth areas of Rocky Mountain National Park and fishing opportunities could potentially draw visitors from across the country and world.

3. Inspire the future: How might your work inform park management?

Our data clearly show that trout density is positively influenced by in-stream wood and old growth unlogged areas of Rocky Mountain National Park have very high density populations of trout. The contrast of streams with high and low amounts of LWD can inform managers how trout populations may be increased by manipulating LWD. Additionally, LWD has additional benefits on natural stochastic events, such and flooding, and may benefit other species as well.

Key words: *trout, woody debris, streams*

Total Mercury Concentrations in 11 Tissues of Cutthroat Trout from Lake Louise, RMNP, CO, USA

Scott **Herrmann** (Colorado State University-Pueblo), Del Nimmo (Colorado State University-Pueblo), James Carsella (Colorado State University-Pueblo), Lynn Herrmann-Hoesing (Washington State University), and Chris Kennedy (U. S. Fish and Wildlife Service). Corresponding author: scott.herrmann@csupueblo.edu

During the past century we have witnessed increases in total mercury (THg) in both terrestrial and aquatic organisms. Two questions relative to cutthroat trout in pristine subalpine and montane lakes kept being asked in our laboratory: (1) how is THg partitioned among soft tissues, and (2) what tissues are significant THg bioaccumulators? These questions led to our working hypothesis: THg bioaccumulates at significantly greater concentrations in kidney and epaxial muscle than in nine other cutthroat trout tissues. To test this hypothesis we collected 10 cutthroat trout from Lake Louise, RMNP, on August 2, 2012. The range in total length was 224 to 437 mm, and in weight 260 to 415 g. After collection the trout were frozen, shipped to CSU-Pueblo; thawed; and processed. Eleven tissues and stomach contents were analyzed by ICP-MS. Mean dry weight (dw) to wet weight (ww) conversion factors for each tissue were also calculated with skin greatest followed by pyloric caecae.

Mean THg ww concentrations were: gonad (ovary [31 µg/kg], testes [21 µg/kg]), skin (9 µg/kg), epaxial muscle (64 µg/kg), liver (55 µg/kg), kidney (110 µg/kg), pyloric caecae (50 µg/kg), gill (32 µg/kg), stomach (34 µg/kg), intestine (36 µg/kg), heart (58 µg/kg), spleen (78 µg/kg), and stomach contents (16 µg/kg). Two external tissues were relatively low, but among internal tissues, kidney was highest followed by spleen and epaxial muscle.

What do these tissue concentrations mean for piscivorous mammals, birds, and even humans? Critical effect threshold concentrations or benchmarks published by US EPA include: 20 µg/kg for fish-eating birds, 100 µg/kg for fish-consuming mammals, and 300 µg/kg as an advisory concentration in epaxial muscle for humans. Most of the methyl mercury (MeHg) in piscivorous birds and mammals is a result of biomagnification. The preferred fish tissues consumed by birds and mammals may play a major role in the movement of THg in their food-chains.

1. Honor the past: Provide a brief historical context for your work.

Mining and related activities have had a minor effect on RMNP relative to mercury (Hg) pollution and long-term Hg contamination. However, small mining towns such as Lu Lu City and Dutchtown did exist within the current boundaries of the park. No local coal-fired power plants, ore smelters, or tire incinerators have impacted Estes Park, Grand Lake, or Rocky. Regional and international sources of elemental gaseous Hg have contributed to the total mercury (THg) load of aquatic habitats in RMNP over the past century. Fish are the primary source of methyl mercury (MeHg) affecting humans, some other mammals, and some birds, and are our best aquatic “canaries”.

2. Celebrate the present: How is your work relevant to park visitors?

Not only is our research on THg in cutthroat trout important to human fishers and consumers, but other “visitors” such as piscivorous birds and other mammals are affected by Hg concentrations in muscle, skin, and other tissues of trout. Bald eagles, ospreys, kingfishers, and other fish-eating birds, along with bear, otter, and mink may be affected acutely or chronically from relatively low concentrations of Hg in various fish tissues.

3. Inspire the future: How might your work inform park management?

What effects will global warming and increased atmospheric discharges of gaseous elemental Hg have on trout in RMNP as well as other high-elevation ecosystems in North America? Is “cold condensation” of Hg occurring in Rocky similar to that in the north and south polar regions? These current data on Hg in fish tissues of cutthroat trout are baseline in nature. We need to continue monitoring Hg concentrations in fish as well as focusing on the sources of Hg using isotopic analysis. Only then can we begin to identify and reduce the levels of THg in our environment.

Key words: *cutthroat trout, Lake Louise, mercury concentrations, tissue bioaccumulation*

Variability of Annual and Monthly Soil Temperature along Trail Ridge Road, Rocky Mountain National Park: 2008 to 2014.

Jason **Janke** (Metropolitan State University of Denver). Corresponding author: jjanke1@msudenver.edu

During the summer of 2008, 30 HOBO temperature data loggers were installed in the alpine tundra along Trail Ridge Road. Each sensor was programed to record temperature every two hours at the soil surface and at a depth ranging from 30 to 50 cm. From 2009 through 2012, mean annual surface soil temperature for all sites showed consistent warming from -1.6° C to 0.3° C. During 2013, the mean annual surface soil temperature returned to below freezing (-1.1° C). A similar pattern with less variation was observed on probes that were installed at greater depths. Examination of mean soil temperature on a monthly scale revealed some unique patterns. For January, mean soil temperatures cooled about -1.0° C from 2009 to 2014. Over the same period, February and March showed no significant change in mean monthly soil temperature. For April, a warming trend of about 1.0° C from 2009 to 2014 was apparent. For May, mean surface soil temperatures have risen by 1.5° C, but still remained just below freezing. Summer soil temperatures have shown the most substantial warming. For June, mean surface soil temperature increased by about 3.5° C from 2009 to 2014. For July and August, mean surface soil temperature has risen 2.0 to 2.5° C on average from 2008 to 2013. The trend continued during September with about 1.0° C warmer mean surface temperature over the same period. No significant change was observed during October from 2008 to 2013. In November and December, mean surface soil temperatures have cooled by about -1.0°C over the same period. In general, the range of summer and winter temperatures have become amplified; summer temperatures have become warmer, whereas winter temperatures have become colder.

1. Honor the past: Provide a brief historical context for your work.

Trail Ridge Road opened in 1932 and is the highest continuously paved road in the US. The road crosses the Continental Divide at Milner Pass (3,279 m) and reaches a maximum elevation of 3,713 m. Permafrost and other ice structures have been described in engineering reports; photos in the Alpine Visitor Center illustrate evidence of construction taking place on frozen soils. If ice is present, the stability of the soils on which Trail Ridge Road rests could be threatened by warming.

2. Celebrate the present: How is your work relevant to park visitors?

This project is designed to continuously monitor climate change in a sensitive alpine ecosystem. Climate change will impact environmental processes. For instance, the timing of snowmelt will affect water supply to reservoirs. Many of the park's visitors come to see beautiful wildflowers in the alpine tundra. Microbial activity, which is influenced by temperature, is an important process to fix nitrogen, an essential element for tundra and wildflower health. As a result, tundra and wildflower species richness and diversity may be affected by small climatic disturbances.

3. Inspire the future: How might your work inform park management?

Roads that are exposed to freezing and thawing can weather and destroy surfaces; data such as these can assist with road maintenance. Managers should expect greater annual variation between summer and winter months, but only slight overall annual warming. Mitigation strategies for preserving alpine tundra could be developed.

Key words: *soil temperature; climate change; Trail Ridge Road; tundra*

Understanding our Spectacular Mountain Landscapes: A Helium Thermochronology Study in Rocky Mountain National Park

Joshua E. **Johnson** (University of Colorado), Rebecca M. Flowers (University of Colorado) and David T. Liefert (University of Colorado). Corresponding author: joshua.e.johnson@colorado.edu

Many of the most impressive and iconic mountain landscapes in the United States are protected under the National Park System. These landscapes are awe-inspiring for millions of visitors, in large part due to their geology. However, mountain landscapes are also some of the most threatened by human activity, and therefore it is imperative to instill a sense of respect and stewardship in those who visit. Understanding *how* those landscapes formed is key to fostering these values in visitors.

Rocky Mountain National Park in the Front Range of northern Colorado is an exceptional place for geologists to interact with the public on the subject of mountain landscapes. The park has a rich geologic history extending back 1.7 billion years that is spectacularly manifested as 72 peaks soaring 12,000 feet (3,700 m) or higher above sea level. Despite the prominence of this mountain landscape, little is known of the details of its long history between the initial formation of the bedrock over a billion years ago, the uplift of the modern mountains approximately 65 million years ago, and the present day. Helium (U-Th/He) thermochronology is an approach that allows one to investigate the thermal histories of rocks – how they cooled as erosion brought them to the surface – and gain insight into topographic and landscape evolution. Samples were collected in the Lumpy Ridge, Mount Ida, and Longs Peak areas of Rocky Mountain N.P. as part of a broader thermochronology study in the Front Range. In addition to addressing previously cryptic portions of this area's geologic history, we intend for this research to serve as an important bridge between scientific research, the park visitors, the mountains they travelled to see, and the driving mission of the National Park Service to preserve these special landscapes.

1. Honor the past: Provide a brief historical context for your work.

The spectacular geology of Rocky Mountain N.P. has drawn scientists to the area for over a century. As early as the 1930s, special reports on the geology of the Park were conducted. More targeted work– including detailed mapping – was done in the 1970s and 1980s, culminating in the publication of a 1:50,000 geologic map of the RMNP in 1990 by USGS scientists William Braddock and James Cole. In 2004, the first low-temperature thermochronologic data (apatite fission-track) were published for the area. There are no published helium thermochronology data for the Park, which serves as a primary motivation for this study.

2. Celebrate the present: How is your work relevant to park visitors?

This work expands our geologic understanding of RMNP. Visitors to the park who are interested in how this impressive landscape evolved over time now have more answers to their questions. In addition to the providing specific information about the geology of the park, this research highlights several broader themes that are relevant to park visitors: 1) the role of RMNP as an exceptional natural laboratory to conduct scientific research, 2) the pace of landscape change on geologic timescales, and 3) the importance of fostering thinking within a scientific framework.

3. Inspire the future: How might your work inform park management?

This work could inform park management in the interpretation division. The results of this research could be incorporated into interpretive programs and exhibits about the geology of the park.

Key words: *geology, tectonics, mountains, thermochronology*

Recovery of riparian vegetation in Moraine Park after the Fern Lake fire

Kristen **Kaczynski** (Colorado State University) and David Cooper (Colorado State University). Corresponding author: kristen.kaczynski@colostate.edu

Severe fire is infrequent in large riparian valleys. We studied the short-term response of riparian vegetation to fire in Moraine Park, Rocky Mountain National Park. We addressed three questions: 1) Does fire differentially affect the survival of alder, willow and river birch; 2) what is the effect of herbivory on post fire willow resprouts, and 3) what are the effects of fire on willow seed dispersal? Vegetation and seed density was monitored the first season post-fire. We mapped canopy death of stems and basal resprouting of 4507 individuals of alder, birch and willow. To examine the effect of herbivory on willow resprouts, we established a paired experiment with 22 willows exclosed in cages to prevent browsing and 22 control willows. Aerial seed rain traps were established on transects throughout the valley and density was compared with pre-fire densities.

Fire effects on willow were severe, with 91% of individuals having complete canopy loss. Fifty-one percent of alder individuals and 71% of river birch individuals had complete canopy loss. Resprouting was common, with 74% of river birch, 45% of willow and 35% of alder resprouting from the base. Willows inside exclosures had greater biomass at the end of the growing season compared with willows outside exclosures. Summer browsing resulted in significantly lower biomass compared with exclosed plants and the interaction of summer and winter browsing resulted in control plants exhibiting 47% less biomass than exclosed plants. Aerial seed rain post-fire was very low throughout the valley and was greater than 90% lower when compared with pre-fire densities.

Fire dramatically altered the riparian vegetation of the study area. Willow seed rain was nearly eliminated and while resprouting woody riparian vegetation was prevalent, ungulate browsing of the resprouting stems could alter the long term persistence of willow, in addition to alder and birch.

1. Honor the past: Provide a brief historical context for your work.

The riparian vegetation community has changed through time in Moraine Park, as this valley has a long history of both anthropogenic and natural disturbances. This research examines the effect of the Fern Lake fire on the riparian vegetation in Moraine Park and examines the recovery of the riparian community.

2. Celebrate the present: How is your work relevant to park visitors?

The Fern Lake fire footprint in Moraine Park is highly visible. Visitors can see charred trees, branches and stumps as they drive along the road or hike along the Cub Lake trail. Many visitors inquire as to how the vegetation is recovering and this research provides insight into the recovery and future restoration of the valley ecosystem.

3. Inspire the future: How might your work inform park management?

Fires are a natural disturbance throughout the Rockies. Little is known about riparian vegetation recovery after fire. This research informs park management about the recovery the dominant vegetation and the impact ungulates may have on the resprouting woody plants.

Key words: *willow, ungulates, fire, restoration, riparian*

History of the Fisheries of Rocky Mountain National Park

Chris **Kennedy** (U. S. Fish and Wildlife Service). Corresponding author: chris_kennedy@fws.gov

Over the course of 12 years historical records were researched to assemble a history of the fisheries of Rocky Mountain National Park (RMNP). Primary sources such as agency reports and fish stocking records were obtained from the RMNP Archives, Colorado Parks and Wildlife, U. S. Fish and Wildlife Service D. C. Booth Historic National Fish Hatchery and Archives, Colorado Historical Society, Colorado State Archives and the U. S. National Archives and Records Administration in Washington, D. C. An abundance of information was also obtained from secondary sources such as local newspapers and oral histories of early Estes Park and Grand Lake residents.

The fish known to be native to the area which would become RMNP were cutthroat trout, suckers and sculpins. These fish were only historically found in the lower reaches of what would become RMNP due to waterfalls and cascades which served as fish migration barriers. Fish stocking in the area began in 1886 and continued with the State of Colorado stocking tens of thousands of fish on an annual basis. In the early 1900s fish hatcheries were constructed in gateway communities of Estes Park and Grand Lake. These hatcheries produced hundreds of thousands of fish annually. The majority of these fish were non-native trout species which were stocked into historically fishless waters. The extensive stocking of fish for recreational fishing altered aquatic landscapes and nearly extirpated native species.

The first formal guidance on management of fish resources provided by the National Park Service came in 1936 and encouraged the stocking of native fish, discouraged the stocking of non-native fish and prohibited stocking of fishless waters. In 1968 fisheries management shifted from an emphasis on recreational fishing to that of recovery of native fish species. The stocking of fish ceased; however, between 1886 and 1968 over 20 million fish had been stocked into RMNP waters. By this time almost all RMNP waters were inhabited by non-native fish species. Under the new management policy 17 native trout reclamation projects have been conducted.

1. Honor the past: Provide a brief historical context for your work.

This research assembles all known historical information on the management of RMNP fisheries resources. From this information the fish species native to park waters and their historic distribution, as well as past management practices are known.

2. Celebrate the present: How is your work relevant to park visitors?

This research will give park visitors an insight as to how fish and why non-native fish species reside in their favorite fishing water.

3. Inspire the future: How might your work inform park management?

By knowing past management practices park management can make informed decisions based on what has worked and hasn't work in the past.

Key words: *fisheries, history, trout*

Estes valley elk population modeling

Alison **Ketz** (Natural Resource Ecology Lab, Colorado State University), Therese Johnson (National Park Service, Rocky Mountain National Park), Mevin Hooten (Colorado State University, U.S. Geological Survey, Colorado Cooperative Fish and Wildlife Research Unit), N. Thompson Hobbs (Natural Resource Ecology Lab, Colorado State University). Contributors: Ryan Monello (National Park Service, Fort Collins), Scott Ratchford (Colorado State University), Janet George (Colorado Parks and Wildlife), Ben Kraft (Colorado Parks and Wildlife), and John Mack (National Park Service, Rocky Mountain National Park). Corresponding author: alison.ketz@gmail.com

Following intensive research and interagency planning, Rocky Mountain National Park is currently implementing an Elk and Vegetation Management Plan that aims to restore a more natural range of variation in elk populations and habitat conditions. The park relies on a variety of management tools to achieve the plan's objectives and monitors results to guide adaptive changes over time. Accurate and reliable elk population estimates are critical to this effort. Since the mid-1990s aerial survey methods have been used as the best means of estimating the number of elk but these methods are expensive and very difficult to implement in windy, mountainous conditions.

The National Park Service initiated research to understand the movements of free ranging elk across the boundary of Rocky Mountain National Park and to develop repeatable ground-based census methods for estimating the abundance throughout the elk winter range. An inter-agency agreement with the National Park Service and Colorado Parks and Wildlife has facilitated gathering park-town cross boundary movement data with radio telemetry. Additionally, monthly ground surveys executed by volunteers have been collected in the park and the town of Estes Park.

We combine these multiple sources of data in a mark-recapture modeling framework using Bayesian estimation. The coupling of movement estimated using telemetry data, along with ground census in this model allows us to overcome the assumption of closure in a Lincoln-Peterson estimator of population size. This enables us to understand the temporal variation across the elk winter range that we can use to compare with management targets.

1. Honor the past: Provide a brief historical context for your work.

The free ranging elk in Rocky Mountain National Park have a long and noble history. Elk were most revered for being an important game species and were elevated to a character in legends by the Ute tribe who occupied the region for thousands of years, as well as for the later arriving Arapahoe tribe. The extirpation of elk in the late 1800s was driven by the flush of European settlers in search of gold, with a taste for elk meat. In 1913, elk were reintroduced to the Estes Valley around the time of the establishment of Rocky Mountain National Park.

2. Celebrate the present: How is your work relevant to park visitors?

The majestic elk are an enormous draw for park visitors, particularly during the rutting season. Bull elk produce the eerie bugle call that echoes through the Estes valley during the autumn months. The elk aggregate in the lower valleys of the park during the fall and tend to stay in these areas across winter, as well as expanding into the town of Estes Park. This population is a major attraction for park visitors, and my work, while on the more technical side of ecology, is an important contribution to maintaining this herd.

3. Inspire the future: How might your work inform park management?

The park service has implemented 45 years of annual and bi-annual helicopter surveys in order to monitor this sub-population. The purpose of this work is to aid the park in changing their survey methods to a safer and more cost effective way. This work directly impacts the management decisions regarding elk for the park service. Knowing how many elk, and the approximate spatial distribution and movement are critical for maintaining the balance of ecosystems in the park.

Key words: *elk, population modeling, survival, abundance, mark-recapture*

Transportation and Management Strategies to Reduce Congestion in the Bear Lake Road Corridor, Rocky Mountain National Park, USA

Jamie Krzeminski (HDR, Inc.); Jason McGlashan (HDR, Inc.); Lilly Hardin (National Park Service, Denver Service Center); and David Pettebone (National Park Service, Rocky Mountain National Park). Corresponding author: jamie.krzeminski@hdrinc.com

The Bear Lake area at Rocky Mountain National Park (ROMO) is one of the signature destinations within the park and one of the most popular with visitors. While visitor access to this area has been improved through the implementation of a park and ride lot with shuttle service, this change originally made to address parking shortages along the Bear Lake Road corridor has also resulted in a doubling of visitation to popular trailheads in the Bear Lake Road corridor. This higher level of visitation now exceeds management objectives with respect to crowding (visitor experience) and resource impacts. A current project at ROMO is considering a suite of strategies to implement solutions to crowding and resource impacts in the Bear Lake Road corridor. These strategies include providing better information in more diverse ways to visitors encouraging them to visit other areas of the park during peak periods and/or to visit the Bear Lake Road corridor outside of the most busy days and times. Other strategies include modifying the existing park shuttle system to serve additional sites outside of the Bear Lake Road corridor that offer similar experiences, and better integrating the park's and Town of Estes Park's shuttle systems to provide a more efficient overall transit system that is seamless to area and park visitors.

This session will provide a broad overview of the current study and recommendations, including:

- Key results from a visitor survey conducted at five locations within the park
- Development and use of a spreadsheet-based visitation scenario management tool to help inform management decisions related to shuttle use, parking, and trail use
- Challenges to modifying the existing shuttle systems, including coordination with the gateway town, Estes Park
- Recommendations for passive management strategies, such as enhanced information, as well as active management strategies, such as shuttle system modifications

1. Honor the past: Provide a brief historical context for your work.

ROMO was one of the first national parks to adopt alternative transportation solutions, initiating a shuttle bus route in the Bear Lake Road corridor in 1978. The system continues to operate during the peak visitor season and service has been increased over time to meet a growing visitor demand. The most recent change was the implementation of the Hiker Shuttle in 2006, which provides service between Estes Park and the Bear Lake Road Park and Ride Lot. System ridership has more than doubled since 2000, rising from approximately 156,000 riders annually in 2000 to more than 330,000 in 2013.

2. Celebrate the present: How is your work relevant to park visitors?

A park's transportation system, including roadways, transit, and trails, can greatly influence a visitor's experience, potentially in a negative way if the visitor experiences unacceptable levels of congestion. Potential modifications to the existing park shuttle system will provide visitors access to less crowded destinations outside the Bear Lake Road corridor and better integration with the Town of Estes Park's existing shuttle system. In addition to providing efficient and effective transit systems, providing increased and enhanced information of park opportunities will allow the park to accommodate increased visitation.

3. Inspire the future: How might your work inform park management?

Project recommendations will provide park management with various passive and active management strategy options that are intended to reduce congestion in the popular Bear Lake Road corridor, while enhancing access to other areas of the park that provide similar experiences. The recommended options will provide for enhanced visitor experience, while still encouraging the protection of natural resources. The transit system is a large part of the park's budget and proposed modifications must be sustainable; as such, the potential park shuttle system modifications are being developed with the intent of being cost-neutral.

Key words: *transportation, shuttle, congestion, visitor experience*

How Distinct is Rocky Mountain National Park's White-tailed Ptarmigan Population? Insights from a Genetic Analysis of Park Birds and Beyond.

Kathryn M. **Langin** (Fort Collins Science Center, U.S. Geological Survey, Colorado State University) Jennifer A. Fike (Fort Collins Science Center, U.S. Geological Survey), Cameron L. Aldridge (Fort Collins Science Center, U.S. Geological Survey, Colorado State University) Gregory T. Wann (Colorado State University), Amy E. Seglund (Montrose Wildlife Service Center, Colorado Parks and Wildlife, and Sara J. Oyler-McCance (Fort Collins Science Center, U.S. Geological Survey, Colorado State University). Corresponding author: klangin@usgs.gov

Knowledge of population-level connectivity and distinctiveness is crucial for making informed management decisions and for predicting how species may respond to climate change. Here, we present a landscape genetic analysis testing factors that constrain gene flow in the white-tailed ptarmigan (*Lagopus leucura*), an alpine species that is widely distributed from Alaska to New Mexico and is of conservation concern because of its vulnerability to climate change. Southern populations of the species are of particular concern because they are geographically isolated and are currently being considered for listing under the U.S. Endangered Species Act. Preliminary genetic analyses using neutral molecular markers (microsatellites) indicate that populations in Colorado, where most of the ptarmigan habitat in the contiguous U.S. is located, are genetically distinct from populations across the rest of the species' range. Within Colorado, there is also evidence for more subtle patterns of genetic differentiation that are partially driven by the geographic distance between populations. We discuss the implications of these results for the conservation of white-tailed ptarmigan in Rocky Mountain NP, as well as future plans to conduct genomic analyses to test for patterns of adaptive genetic divergence across populations exposed to different climatic conditions.

1. Honor the past: Provide a brief historical context for your work.

In a world with mounting conservation challenges, alpine species are relatively unique in that many of them have been untouched by anthropogenically-driven habitat loss and fragmentation – so their historical ranges have remained relatively intact. This provides an opportunity to quantify natural levels of connectivity across the landscape ahead of future impacts that may be brought on by climate change.

2. Celebrate the present: How is your work relevant to park visitors?

Rocky Mountain NP is one of the most accessible locations in North America for viewing white-tailed ptarmigan, and many visitors to the park specifically seek out this species. Our work will provide context as to how this population compares to populations across the rest of the species' range.

3. Inspire the future: How might your work inform park management?

White-tailed ptarmigan have been monitored in Rocky Mountain NP since the 1960s. This long-term program provides one of the most robust baselines for assessing how an alpine population responds to future changes in climate. That said, the park population does not occur in isolation; it is surrounded by peaks that harbor white-tailed ptarmigan habitat. Our study seeks to understand the degree to which these populations are connected across the landscape. This will allow us to identify where immigrants to the park population are likely coming from, and to predict potential impacts to connectivity should populations be lost in the future.

Key words: *climate change, connectivity, landscape genetics, white-tailed ptarmigan*

Ozone Bioindicator Gardens: an Educational Tool to Raise Awareness about the Northern Colorado Front Range Ozone Pollution and its Effects on Living Systems

Kateryna **Lapina** (Department of Mechanical Engineering, University of Colorado at Boulder) and Danica Lombardozzi (National Center for Atmospheric Research). Corresponding author: kateryna.lapina@colorado.edu

High concentrations of ground-level ozone cause health problems in humans and a number of negative effects on plants, from reduced yield for major agricultural crops to reduced amounts of carbon stored in trees. The Northern Colorado Front Range region has been exceeding the National Ambient Air Quality Standard for ozone for more than fifteen years during summer months, and efforts to reduce ozone levels are hampered by the presence of diverse pollution sources and complex meteorology in the region. High levels of ozone have been regularly observed in the Rocky Mountain National Park (RMNP). In addition to having negative effects on the health of park visitors, a multi-year study documented injury on ozone-sensitive plants growing in the park. To raise public awareness of air quality in RMNP and Colorado's Front Range, and to educate all age groups about ground-level ozone, two ozone bioindicator gardens were planted in Boulder in Spring 2014. The gardens contain ozone-sensitive bioindicator plants that develop a characteristic ozone injury when exposed to high levels of ozone and include a native species of cutleaf coneflower (*Rudbeckia laciniata* var. *ampla*) collected from RMNP. The ozone gardens are providing the general public with a real-life demonstration of the negative effects of ozone pollution through observable plant damage. Additionally, the gardens are useful in teaching students how to collect and analyze real-world scientific data.

1. Honor the past: Provide a brief historical context for your work.

The levels of ground-level ozone have been increasing in the last several decades and currently pose a threat to human health and vegetation in the park.

2. Celebrate the present: How is your work relevant to park visitors?

Our work aims to educate park visitors on ozone pollution and raise their awareness of the problem.

3. Inspire the future: How might your work inform park management?

We hope that park management will establish their own ozone bioindicator garden at the park to educate their visitors on air pollution problem.

Key words: *ozone, air pollution, effects on plants, bioindicators, public education*

Influences on Future Leave No Trace Behavior in National Parks

Ben **Lawhon** (Leave No Trace Center for Outdoor Ethics – Boulder, Colorado) and Derrick Taff (Penn State University).
Corresponding author: Ben@LNT.org

In many protected areas resource degradation due to inappropriate visitor behavior is a significant concern for managers. Given the fact that even nominal recreational use can cause considerable impacts, particularly since some impacts are cumulative over time, park managers must utilize a variety of strategies to minimize these impacts. In many parks, managers provide minimum-impact visitor education in the form of the seven Leave No Trace principles for responsible recreation. The Leave No Trace concepts and principles have become one of the most frequently used methods for encouraging responsible use of recreational resources. The intent of Leave No Trace is to educate recreationists about the nature of their impacts with the goal of resource protection.

In spite of recent advances towards understanding attitudes and behaviors related to Leave No Trace of backcountry recreationists, there is a dearth of information pertaining to the attitudes frontcountry visitors have towards Leave No Trace recommended practices. Frontcountry, as defined by The Leave No Trace Center for Outdoor Ethics, includes areas that are easily accessed by car and mostly visited by day users. In many parks and protected areas, park managers direct most visitors to frontcountry locations.

This study examined psychological and knowledge variables that were hypothesized to influence future Leave No Trace behavior in Rocky Mountain National Park. Data were obtained from an on-site survey administered to individuals (n = 390, response rate 74%) in the Bear Lake corridor of the park. Results of a multiple regression revealed that *perceived effectiveness* of Leave No Trace practices is the strongest predictor of future behavior ($\beta > .21$, $p < .001$, in all cases). Frontcountry visitors like those at Bear Lake are more likely to practice Leave No Trace if they perceive the principles to be effective at reducing impacts.

1. Honor the past: Provide a brief historical context for your work.

Despite long-term, robust Leave No Trace educational efforts by Rocky Mountain National Park, recreation-related impact continues to be a concern for park managers. Many park visitors may be unaware of both the nature of their impacts and Leave No Trace practices to reduce those impacts. This study examined the influence of attitudes, perceived effectiveness, perceptions related to the difficulty of following practices, and self-reported knowledge on future Leave No Trace behavioral intent in Rocky Mountain National Park. Of particular interest was determining which of these variables has the most influence on future visitors' behavioral intent.

2. Celebrate the present: How is your work relevant to park visitors?

Leave No Trace is the most prevalent minimum-impact visitor education program in use in parks and protected areas in the U.S. The intent of the program is to educate recreationists about the nature of their recreational impacts with the goal of resource protection. Leave No Trace is particularly appealing to both park visitors and land managers because it offers a more light-handed approach to visitor management as opposed to more heavy-handed management strategies. Park visitors need to better understand why certain Leave No Trace practices are recommended, and why those practices are effective at reducing impacts.

3. Inspire the future: How might your work inform park management?

This study examined variables though to influence future Leave No Trace behavioral intent in park visitors. If specific influences can be determined, park managers can effectively message to visitors about how to minimize their recreation-related impacts. Results indicate that managers should focus educational efforts on how effectively Leave No Trace practices minimize impacts to the landscape. While this study found that that knowledge is not a significant predictor of behavioral intent, park visitors do need to be made aware of the recommended Leave No Trace practices for Rocky Mountain National Park.

Key words: *Leave No Trace, Influencing behavior, Recreation impacts, Visitor Attitudes and Behavior*

Measuring and Monitoring Wilderness Character in Rocky Mountain National Park

Colin **Leslie** (Colorado State University), David Pettebone (Rocky Mountain National Park), and Peter Newman (Penn State University). Corresponding author:coffeeclimber@gmail.com

The Wilderness Act of 1964 established the National Wilderness Preservation System and mandated for the preservation of wilderness character within areas designated as wilderness. While the preservation of wilderness character is the fundamental aim of wilderness protection, methods for measuring and monitoring the efficacy of wilderness stewardship at meeting this mandate have until recently been insufficient. In 2008, *Keeping it Wild: An Interagency Strategy to Monitor Trends in Wilderness Character Across the National Wilderness Preservation System* was released, providing one of the first comprehensive frameworks specifically focused on assessing wilderness character.

Our study took place over a two year period between 2012 and 2014 and focused on identifying and evaluating existing programs and data capable of supporting a wilderness character monitoring program for Rocky Mountain National Park Wilderness. In addition to evaluating existing wilderness data sources, we developed a pilot study to test observer based source identification logging as a method for rapidly assessing soundscapes in wilderness at a landscape scale. Findings from our study indicate that a robust inventory of existing, high quality, programs and data currently exist that are informative of one or more qualities of wilderness character for Rocky Mountain National Park Wilderness. In a number of instances, we identified multiple data sources for a single wilderness monitoring measure and therefore determined a more detailed analysis was required to understand tradeoffs among similar data sources. To assist with this analysis we included two additional frameworks focusing specifically on assessing measures of significance, vulnerability, reliability, feasibility, and spatial coverage of each data source as it related to wilderness management. Results from this additional analysis suggest that some data gaps, particularly in spatial coverage, exist as well as notable variability among remaining measures. It should also be noted that these results are best suited not as prescriptive findings, but rather as a comprehensive reference for future wilderness planning efforts. Finally, results from our pilot study on observer based source identification logging indicate this method has potential as a viable method for rapidly assessing soundscapes at landscape scale.

1. Honor the past: Provide a brief historical context for your work.

Our study was prompted by the confluence of three important developments: the formal designation of Rocky Mountain National Park Wilderness in 2009, the release of *Keeping it Wild: An Interagency Strategy* in 2008, and the upcoming 50th anniversary of the Wilderness Act in 2014. In the first few decades after the passage of the Wilderness Act of 1964, wilderness preservation was dominated by designation of new areas. In contrast, this study focuses on the growing interest among wilderness managers in trying to understanding how effective stewardship efforts are at maintaining the primary objective of wilderness designation, preserving wilderness character.

2. Celebrate the present: How is your work relevant to park visitors?

Even though Rocky Mountain National Park Wilderness was only officially designated in 2009, it has been managed as de facto wilderness since the early 1970s. While not all visitors may realize it, the majority of the park landscape (94%) in which they hike, backpack, climb, view wildlife, or enjoy the many natural wonders the park has to offer is designated official wilderness. To preserve this landscape now and into the future is to preserve the very essence of what draws millions of visitors to Rocky Mountain National Park every year.

3. Inspire the future: How might your work inform park management?

Effective wilderness management requires integrating a diverse array of park operations and scientific disciplines so that a comprehensive understanding of wilderness as a whole can be developed. This study can help inform park management by bringing together often disparate sources of information so that they can be examined collectively when evaluating the current status of wilderness in the park as well as serving as reference for future planning efforts.

Key words: *wilderness, wilderness character, soundscapes, monitoring*

Understanding the effect of a large-scale bear-proofing effort on human-black bear conflict

Stacy A. **Lischka** (Colorado Parks and Wildlife) and Heather E. Johnson (Colorado Parks and Wildlife). Corresponding author: stacy.lischka@state.co.us

Conflicts between humans and black bears are increasing across the U.S. and in some areas of Colorado. Wildlife managers struggle to address these conflicts because conventional management actions (e.g. increasing harvest, trapping and translocating problem bears, and euthanasia of problem bears) have limited success in alleviating conflict and can be controversial among residents. It has been suggested that the most effective way to reduce black bear-human conflict in urban areas may be to limit the availability of anthropogenic food sources to bears, yet we know little about the effects of large-scale efforts to bear-proof human food on conflict rates. Limiting anthropogenic food such as garbage, bird feeders, pet food and fruit trees requires the support of residents across a community, not just those experiencing conflict; however, current approaches to encouraging these behaviors have not achieved rates of bear-proofing necessary to affect conflict rates. By employing an experimental approach in which we distributed free, bear-resistant garbage containers to a portion of the residents of Durango, Colorado, we aim to measure the effect of a large-scale effort to bear-proof garbage on conflict rates and bear use of urban landscapes. In addition, we are monitoring appropriate use of bear-proof garbage containers by residents and resident attitudes about bears and their management. Preliminary findings of this project will be discussed in the context of identifying and testing the effectiveness of novel approaches to managing human-black bear conflict.

1. Honor the past: Provide a brief historical context for your work.

The rate of conflicts between people and bears has increased as human development has reached farther into natural, high quality bear habitats. These conflicts may cause residents to demand that wildlife managers work to limit the negative effects of conflicts on people. To do so, we must understand the factors contributing to conflicts and the role of management actions in alleviating conflict. Efforts to reduce conflicts between bears and people will encourage co-existence and help ensure that bear populations persist into the future.

2. Celebrate the present: How is your work relevant to park visitors?

Visitors are drawn to Rocky Mountain National Park by the chance to view wildlife species such as black bears in scenic habitats. While interactions with bears inside the park may be desirable, bears may also cause conflicts when they enter human-dominated landscapes such as residential areas and campgrounds. Bears involved in conflicts are at increased risk of mortality from vehicle collisions and conflict-related removals. Efforts to limit factors that attract bears to developed areas may reduce the number of bears that venture into these areas, reducing the chance of negative bear-human interactions and conflict-related bear mortality.

3. Inspire the future: How might your work inform park management?

Many municipalities, parks and other jurisdictions have considered requiring the use of bear-proof garbage containers for residents and visitors through establishment of bear-proofing ordinances. These ordinances require a substantial financial investment. To justify such an investment, these entities need to know whether this management strategy will be effective. In addition, ordinances require that residents and visitors use garbage containers appropriately. Understanding the effect of these regulations on human behavior, conflict activity, and bear movements will be critical to ensuring the regulations achieve the desired result of reducing conflicts between humans and black bears.

Key words: *Human-black bear conflict, bear-proofing, human dimensions, garbage*

Instream wood loads, channel complexity, and ecological potential in forested, headwater streams under alternative stable states in Rocky Mountain National Park

Bridget **Livers** (Colorado State University), Ellen Wohl (Colorado State University), and Nicholas Sutfin (Colorado State University). Corresponding author: bridgetlivers@gmail.com

Channel morphology and irregularities in stream boundaries can create zones of flow separation, where lower velocities trap fine sediment and organic matter, increasing habitat potential and opportunities for nutrient processing and biological uptake. This effect is most pronounced with channel-spanning structures such as logjams. Humans have extensively changed spatial and temporal characteristics of instream wood distribution, with lasting effects on instream wood recruitment, storage, logjam distribution, and ecology. Previous studies in the Colorado Front Range (CFR) show that contemporary headwater streams flowing through old-growth, unmanaged forests have greater wood volumes than streams flowing through younger-growth, managed forests, but do not evaluate the effects of wood on channel complexity. 'Managed' versus 'unmanaged' refers to whether forests were or are currently exposed to human alteration. Rocky Mountain National Park (RMNP) still contains unmanaged forests, but is subject to natural disturbance. Although some human alteration has long since ceased, reduced wood loads in managed streams persist. Our primary objective was to quantify differences in logjams, wood volumes, stream complexity, and organic carbon storage on streams with different management and disturbance histories in order to examine legacy effects across a gradient of stream management. Data were collected during the summers of 2013 and 2014 in RMNP and nearby Medicine Bow National Forest. The 24 stream reaches studied are 2nd to 3rd order, subalpine streams categorized into: old-growth unmanaged forests; younger, naturally disturbed unmanaged forests; and younger managed forests. We assessed instream and floodplain wood loads, local channel complexity, pool volume, and storage of organic carbon. Preliminary results show that greatest wood and carbon storage in sediments, as well as channel complexity, occurs in streams in old-growth, unmanaged forests and lowest wood and carbon storage and channel complexity occurs in younger-growth, managed forests. Younger, unmanaged forests are closer to old-growth forests than to managed forests.

1. Honor the past: Provide a brief historical context for your work.

Rocky Mountain National Park is unique in the Colorado Front Range because its National Park status has protected the area from human alteration, which has in turn retained relatively pristine, undisturbed streams, forests, and ecosystems within its borders. This provides a special opportunity to perform research in the park and compare these historically preserved streams, forests, and related ecosystems to areas outside the park that have been subjected to human disturbance. In addition, our research evaluates how historical natural disturbances, such as fire and tree blowdowns, affect stream ecosystems in the park.

2. Celebrate the present: How is your work relevant to park visitors?

Forests and streams are prime features for visitors of the park, whether on trails or in the backcountry. This research will communicate the importance of instream wood not only on the maintenance of headwater streams, but on the ecological importance of logjams as habitat for fish and other creatures important to park visitors and the natural occurrence of tree mortality. Furthermore, the role of storage and potential for Rocky Mountain National Park headwater streams to serve as carbon sinks is important to park visitors interested in the effects of climate change.

3. Inspire the future: How might your work inform park management?

If old-growth, unmanaged headwater streams in Rocky Mountain National Park facilitate logjams and associated biological hotspots, protecting wood recruitment mechanisms in the park becomes a means of protecting stream-riparian ecosystems. Naturally disturbed forests in the park, such as burn scars, blowdowns, or pine beetle infestations, should be left to recover on their own and contribute to the recruitment of instream wood. Managers can use this research on instream wood to develop restoration and resource management goals. This research will also provide managers with information on carbon storage and how climate change may affect stream function and processes in headwater streams.

Key words: *instream wood, headwater streams, carbon storage*

Genomics of inbreeding depression and genetic rescue of the last greenback cutthroat trout

Sierra Love **Stowell** (University of Colorado); Kevin Rogers (Colorado Division of Parks & Wildlife), and Andrew Martin (University of Colorado). Corresponding author: lovestowell@gmail.com

The cold, swift waters of Rocky Mountain National Park were once home to two divergent lineages of cutthroat trout. Today, the lineage native to the South Platte drainage on the east side of the park is teetering on the brink of extinction: a single remnant wild population persists in a small stream in the Arkansas drainage to the south. Individuals from this wild population in Bear Creek are being propagated in a state fish hatchery with the intent of reestablishing wild populations within the South Platte drainage. Genetic analysis shows that depleted genetic diversity and reduced fitness are common in the hatchery population, both suggestive of inbreeding depression. To determine the extent of genetic diversity and inbreeding depression in the wild Bear Creek population, we bred Bear Creek adults with cutthroat trout from another subspecies native to the Colorado River drainage (Carr Creek) and sequenced portions of the genome to identify variation within and between the two populations. We measured survival and growth of all offspring in a common environment. We extracted and barcoded DNA from all parents and a subset of the offspring. Using next generation sequencing, we found several hundred SNPs between the two lineages, and multiple SNPs that allowed assignment of parentage to the offspring. We found that outbred offspring show significantly higher fitness than inbred offspring, suggesting recovery from inbreeding depression by genetic rescue. Intriguingly, not all parents in the cross contributed equally to the pool of surviving offspring. In general, the quantification of inbreeding depression can be used to plan genetic rescue and breeding efforts in a diversity of taxa threatened by small population size. Additionally, knowledge of inbreeding and genetic diversity can be used to predict the success of reintroduction efforts of Bear Creek cutthroat trout back into the South Platte drainage and RMNP.

1. Honor the past: Provide a brief historical context for your work.

Rocky Mountain National Park is in the heart of the native range of the greenback cutthroat trout in the South Platte drainage. RMNP played a central role in the recovery of what was thought to be the native greenback cutthroat trout from the 1970s through the early 2000s. While recent research demonstrated that what was stocked into the South Platte during that period was actually native to west of the Continental Divide, the Park remains home to many populations of cutthroat trout.

2. Celebrate the present: How is your work relevant to park visitors?

Cutthroat trout are an important and charismatic component of the biodiversity of RMNP and the American West. Visitors come to the Park to see wildlife in their native habitat; historic and recovery populations of cutthroat trout will continue to attract visitors and anglers to high altitude lakes, streams, and rivers of the Park.

3. Inspire the future: How might your work inform park management?

Management decisions are made with the best available science that is currently available. As our understanding of the distribution of native biota and the human and environmental forces that shape it changes, management decisions also change. RMNP was a central part of the previous recovery effort and will likely continue to be so as we move forward with the reintroduction of native South Platte lineage of cutthroat trout. Our research will help inform what stock is reintroduced into the South Platte and help determine the conservation value of hybrid and non-native cutthroat trout populations.

Key words: *cutthroat trout, genetics, inbreeding, reintroduction*

Identifying Natural Resource Constraints and Opportunities for Alternative Recreation Sites to the Bear Lake Corridor, Rocky Mountain National Park, USA

Laura **Lutz-Zimmerman** and Jamie Krzeminski (HDR, Inc.). Corresponding author: laura.lutz-zimmerman@hdrinc.com

The Bear Lake area at Rocky Mountain National Park (ROMO) is one of the most popular with visitors. To address parking shortages along the Bear Lake Road corridor and accommodate an increasing visitor demand, the park established a park and ride lot with shuttle service. While the shuttle system has provided numerous benefits, it has also resulted in a doubling of visitation to popular trailheads in the corridor, compared to auto only access, since visitation to trailheads is no longer regulated by trailhead parking lot sizes. This higher level of visitation now exceeds management objectives with respect to crowding (visitor experience) and resource impacts.

A current project at ROMO is considering a suite of strategies to implement solutions to crowding and resource impacts in the Bear Lake Road corridor. These strategies include providing better information in more diverse ways to visitors encouraging them to visit other areas of the park during peak periods and/or to visit the Bear Lake Road corridor outside of the most busy days and times. Other strategies include modifying the existing park shuttle system to serve additional sites outside of the Bear Lake Road corridor that offer similar experiences and better integrating the park's and Town of Estes Park's shuttle systems to provide a more efficient overall transit system that is seamless to area and park visitors.

This poster will highlight the findings of natural resource studies, including the resiliency at each of the five alternatives sites to handle additional visitor use. The conundrum of the findings is that the least resilient sites were the best sites for providing additional access including shuttle service modifications. The research emphasizes the difficulty in decision making to balance visitor use and resource management.

1. Honor the past: Provide a brief historical context for your work.

Recreation opportunities in ROMO have changed over time to meet changes in visitor demand. Each change results in impacts to the natural environment within the park, ultimately affecting visitor experience. To address crowding concerns along the Bear Lake corridor, five alternative sites have been identified shift visitor use. Two of the alternative sites under consideration were former lodges, one a ski area, and one resulted from a flood. Just as these former uses have been affected by previous management decision, shifting visitor use to these sites will again affect the landscape and resources.

2. Celebrate the present: How is your work relevant to park visitors?

Visitor experience is greatly influenced by the actual and perceived level of degradation to the natural environment. Potential modifications to the existing park shuttle system will provide visitors access to less crowded destinations outside the Bear Lake Road corridor. However, if the resources at these alternative sites are being degraded as a result of the existing use, current and future visitor experience can be diminished. It is important to establish an overall environmental baseline condition at these sites.

3. Inspire the future: How might your work inform park management?

The overall project makes recommendations for reducing congestion along the Bear Lake Corridor through passive and active management strategies, including dissemination of information to encourage voluntary shifts in visitor use and changes in shuttle service to alternative sites. The natural resource and resiliency evaluation at each alternative site will assist park management in implementing these strategies and developing solutions to minimize negative impacts the natural environment and visitor experience.

Key words: *natural resources, resiliency, visitor experience*

The Genetic Legacy of more than a century of stocking trout: a case study in Rocky Mountain National Park, Colorado, USA

Andrew **Martin** (University of Colorado), Sierra Love-Stowell (University of Colorado), and Chris Kennedy (USFWS).
Corresponding author:am@colorado.edu

Human introductions can obscure the diversity and distribution of native biota, especially in aquatic habitats. Hybridization with and replacement by non-native congeners is a primary conservation threat, particularly in salmonids. Cutthroat trout are an important component of biodiversity in the American West and all recognized subspecies are targets for state and federal conservation efforts. Rocky Mountain National Park (RMNP) in northern Colorado is a microcosm of trout introductions that have happened worldwide. We used a combination of extensive stocking records and molecular genetic data to ask two main questions: 1) whether native trout populations persist in spite of stocking; 2) if patterns in the distribution of cutthroat trout clades could be explained by source and intensity of stocking. Nearly 15 million cutthroat trout were stocked into RMNP from a mosaic of sources in the 20th century. A single lineage of cutthroat trout was originally native to each side of the Continental Divide in RMNP. We detected at least five divergent clades of cutthroat trout across the 34 localities surveyed. The distribution of lineages was predicted by stocking pressure and source but not by what lineage was historically native. The future of mixed and non-native populations of cutthroat trout in RMNP poses a substantial conservation challenge.

Key words: *Cutthroat trout, microsatellites, mitochondrial DNA, stocking*

Links between N Deposition and Nitrate Export from a High-Elevation Watershed in the Colorado Front Range

Alisa **Mast**, David Clow, Jill Baron, and Greg Wetherbee (US Geological Survey). Corresponding author: mamast@usgs.gov

Long-term patterns of stream nitrate export and atmospheric N deposition were evaluated over three decades in Loch Vale, a high-elevation watershed in the Colorado Front Range. Stream nitrate concentrations increased in the early 1990s, peaked in the mid-2000s, and have since declined by over 40%, coincident with trends in nitrogen oxide emissions over the past decade. Similarities in the timing and magnitude of N deposition provide evidence that stream chemistry is responding to changes in atmospheric deposition. The response to deposition was complicated by a drought in the early 2000s that enhanced N export for several years. Other possible explanations including forest disturbance, snow depth, or permafrost melting could not explain patterns in N export. Our results show that stream chemistry responds rapidly to changes in N deposition in high-elevation watersheds, similar to the response observed to changes in sulfur deposition.

1. Honor the past: Provide a brief historical context for your work.

The Loch Vale Watershed has been a site of long-term monitoring and ecological research since 1982. Research has focused on watershed-scale ecosystem processes, particularly as they respond to atmospheric deposition and climate variability. This study examines changes in the water quality of 2 streams in Loch Vale over the past 3 decades.

2. Celebrate the present: How is your work relevant to park visitors?

High-elevation lakes and streams in the park are a major attraction for visitors who value them for their beauty, remarkable water clarity, and trout fisheries. Increases in atmospheric deposition of N could threaten the water quality, transparency and biological integrity of these aquatic ecosystems. Improved understanding of the controls on N export in streams is needed to protect this sensitive resource from damage related to air pollution.

3. Inspire the future: How might your work inform park management?

These results are important in light of recent policy efforts to reduce N deposition in RMNP as part of the Nitrogen Deposition Reduction Plan. Our results suggest that reductions in N deposition on a regional scale should result in fairly immediate declines in stream nitrate concentrations in LV and in other high-elevation watersheds in the Colorado Front Range. However, climate variability may mask improvements in stream chemistry and needs to be considered when evaluating the effectiveness of deposition reduction strategies.

Key words: *nitrogen deposition, stream chemistry, Loch Vale*

Forecasting the Potential Impacts of Climate Change, Insects, and Pathogens on Limber Pine in Rocky Mountain National Park

William B. Monahan (NPS Inventory and Monitoring Division). Corresponding author: Bill_Monahan@nps.gov

Resource managers at parks and other protected areas are increasingly expected to factor climate change explicitly into their decision making frameworks. Five needle pine management is especially challenging because tree disease may exacerbate climate impacts in complex ways. Here, using climate-based ecological niche models that forecast potential distributions through 2100, plus near-term estimates of tree mortality from the USFS 2013-2027 National Insect and Disease Rick Map, I quantify the potential impacts of climate change and disease on limber pine (*Pinus flexilis*) in Rocky Mountain National Park. Climate models are trained locally within the park where limber pine is the community dominant tree species, a distinct structural-compositional vegetation class of interest to managers, and also rangewide, to evaluate broader species-level climatic sensitivities. Climate model forecasts through 2100 under two emissions scenarios (representative concentration pathways 4.5 and 8.5 Watts/meter^2) show that the distribution of limber pine in the park is expected to move upslope in elevation, but changes in total and core patch area remain highly uncertain. Disease risk projections further identify areas within the park where limber pine is expected to suffer declines in basal area, which depending on the magnitude may feed back into the niche models to either encourage persistence or accelerate loss. Results are used to rank the combined impacts of future climate change and disease on limber pine throughout the park, assess overall vulnerability to these future changes, and ultimately develop management scenarios that realistically bracket and address the range of plausible futures.

1. Honor the past: Provide a brief historical context for your work.

Limber pine is a long-lived species, with some individuals surviving over 1000 years. Related, limber pine has persisted throughout past periods of environmental change. Given its successful history, how could climate change now and in the future threaten limber pine? The answer emerging from this study is two-fold. First, climate change is occurring at an especially rapid rate, relative to past rates of paleoenvironmental change, and the rate of potential colonization of new habitats. Second, climate change is not operating in isolation, but rather in concert with other environmental changes and processes that can exacerbate declines.

2. Celebrate the present: How is your work relevant to park visitors?

Limber pine is an iconic species in the subalpine forests of Rocky Mountain National Park. The twisted, gnarled trees are a key defining feature of the park landscape. In addition, limber pine influences important ecosystem services, including food provisioning for wildlife, post-fire forest establishment, and snow retention. Changes to these services, mediated in part by changes in limber pine, could negatively impact other valued park resources.

3. Inspire the future: How might your work inform park management?

Model results suggest that the future of limber pine in Rocky Mountain National Park will be shaped by management practices in two major habitats. The first is existing habitats, which are generally anticipated to remain climatically suitable for limber pine, but also for the more shade-tolerant and competitive conifers that – in the absence of disturbance – could outcompete limber pine. The second is in new upslope habitats, areas that are presently alpine, where managers might face the tough choice of deciding whether to facilitate or impede an elevational range expansion of subalpine limber pine.

Key words: *limber pine, climate change, disease, management scenarios*

Prions in plants: assaying grasses from rocky mountain national park for PrP^{CWD}

Aimee **Ortega** (Colorado State University Prion Research Center), Jan Leach (Colorado State University, Department of Bioagricultural Sciences and Pest Management), Jeffrey Seligman (Colorado State University Prion Research Center), and Mark Zabel (Colorado State University Prion Research Center). Corresponding author: aimee.ortega@colostate.edu

Chronic wasting disease (CWD) affects cervids such as elk, deer, and moose and has become endemic over the last decade. The disease is one of many transmissible spongiform encephalopathies which occur due to the accumulation of an abnormally folded, proteinase K resistant, form of the normal cellular prion protein PrP^{C}. This abnormally folded form, PrP^{CWD}, seeds conversion of PrP^{C} into PrP^{CWD} and eventually forms amyloid fibrils. The exact mechanisms behind transmission and spread of CWD are unknown but research has shown that it can be spread through direct animal to animal contact or via indirect exposure to contaminated feed and water sources. We want to further explore the latter and determine whether prions can be detected in grasses and other plants in ROMO by use of the protein misfolding cyclic amplification (PMCA) assay.

This past summer we surveyed three sites within ROMO and collected a total of 32 plants. Plants were collected from both outside and inside enclosures that serve to keep wildlife out and allow for restoration and regrowth of the flora. Plant samples were decontaminated and then assayed them for detection of PrP^{CWD}.

1. Honor the past: Provide a brief historical context for your work.

Since the discovery of Chronic wasting disease (CWD) in 1967 in captive deer CWD has spread to free ranging deer, elk, and moose in 19 states in the United States, 2 Canadian provinces, and South Korea. Prevalence in captive herds have reached as high as 90%. We have been measuring CWD prevalence in a large herd within ROMO, with most recent estimates reaching 19%. Wyoming mule deer CWD prevalence of 50% has been reported in certain areas. Determination of an environmental reservoir of PrPCWD will hopefully provide insight in order to halt the spread of CWD in ROMO and beyond.

2. Celebrate the present: How is your work relevant to park visitors?

If PrPCWD is able to detected in or on the surface of plants it could serve as an environmental reservoir. This information might help to assuage certain fears, worries, or misconceptions about CWD.

3. Inspire the future: How might your work inform park management?

Discovery of an environmental reservoir would provide park management a new area to target in order to try and curtail the spread of Chronic wasting disease (CWD).

Key words: *elk, wildlife disease, prions*

Understory Vegetation Response to Mountain Pine Beetle-Induced Lodgepole Pine Mortality in Rocky Mountain National Park

Gregory **Pappas** (University of Wyoming), Daniel Tinker (University of Wyoming) and Monique Rocca (Colorado State University). Corresponding author: gpappas@uwyo.edu

Understory plants are an important element of forests, having a considerable influence on biodiversity, wildlife habitat, and ecosystem function. A recent bark beetle epidemic across western North American forests has caused unprecedented overstory tree mortality, creating new growing conditions that provide the opportunity for changes in the abundance, diversity, and composition of plants within the intact understory. We employed a repeated measures approach to describe the changes in understory vegetation over a five-year period (2008-2013) following peak mountain pine beetle (MPB) activity across lodgepole pine-dominated forests in western Rocky Mountain NP. We characterized the temporal changes in plant cover, richness, diversity, functional groups, and community composition. Additionally, we used forest structure and environmental variables to model these changes across spatial scales and investigate potential mechanisms driving the response. Results show that understory plant cover tended to increase in areas where live tree basal area decreased, suggesting a positive response to the immediate effects of tree death (i.e., increases in available resources). Graminoid cover increased on average across the study area and especially in stands dominated by a later outbreak stage. Forb and shrub cover was relatively unaffected or decreased slightly overall. Average richness per plot increased, yet changes in species frequencies varied widely. For example, Ross's sedge, a common understory species that is often characteristic of open canopy forests, increased in frequency by 158%, while the green-flowered wintergreen, a small forb that prefers shade, decreased in frequency by 35%. While shrubs remain the dominant life form, graminoid and forb species increased in relative dominance. Introduced species such as dandelion and Canada thistle more than doubled in frequency. Exploring the changes in plant functional groups and traits may help predict how ecosystem functioning has been altered as a result of the MPB outbreak, serving to better inform conservation and management efforts.

1. Honor the past: Provide a brief historical context for your work.

Lodgepole pine forests on the west side of the park regenerated following stand-replacing fires in the 1800s. Although fire is the dominant disturbance agent determining stand structure and development, wind and insects may also cause significant destruction resulting in heterogeneous stands that vary in species composition and successional stage. The park has experienced small MPB outbreaks periodically over the last century, however, the most recent outbreak exceeds all others in recorded history in terms of extent and severity. The park completed a vegetation-mapping program in 2005. The results of our plant community analyses may complement the information from this program.

2. Celebrate the present: How is your work relevant to park visitors?

Rocky Mountain NP is undeniably one of the nation's most extraordinary places. Along with its indispensable ecosystem services, the park maintains aesthetic and cultural resources that people from all over the world travel to see and experience. From the rare orchid to the ubiquitous yellow aster, understory plants are among the foremost of resources when it comes to visitor enjoyment. An educated awareness of the changes in post-outbreak plant communities and their ecological implications will help visitors appreciate the complexity of forest systems, eliciting a deeper connection to the environment and a desire to preserve and study the natural world.

3. Inspire the future: How might your work inform park management?

Ecosystem response to disturbance is a chief ecological and management concern. This study's findings may convey important changes in wildfire risk, wildlife habitat, and the quantity and distribution of invasive plant species throughout the park. Consequently, it may serve to identify specific areas where management might be necessary to facilitate park objectives. Quantifying changes in plant functional groups and community trait variation allows for the prediction of how ecosystem function is altered following disturbance. Employing trait-based approaches in ecological research may provide more meaningful information regarding understory plant response, resulting in improved conservation and management efforts within disturbed systems.

Key words: *plant communities, understory, vegetation, mountain pine beetle, lodgepole pine*

Trends in accumulation and melt of seasonal snow in Rocky Mountain National Park

Glenn G. **Patterson** (EASC-Watershed Science, Colorado State University) and Steven R. Fassnacht (Colorado State University, Cooperative Institute for Research in the Atmosphere)

The seasonal snowpack in Rocky Mountain National Park is critical to the local and downstream water supply and the ecosystem of the park, and is important for winter recreational opportunities. Recent regional studies have illustrated that snow accumulation is decreasing, averaging on the order of -2 to -4 cm/decade; snowmelt is tending to be earlier, averaging on the order of -2 to -4 days/decade. Trends specific to Rocky Mountain National Park are similar but not totally uniform. From 30+ years of daily snow water equivalent (SWE) data collected at thirteen NRCS Snowpack Telemetry (SNOTEL) stations in and near the park, April 1 SWE has been changing by -4.7 to +1.1 cm/decade, with most stations slightly decreasing yet many of the changes being statistically significant. Trends in date of peak SWE were also increasing and decreasing, ranging from -4.4 to +3.2 days per decade. Monthly records from longer-term NRCS snow courses suggested that some declining trends began as early as the late 1930s, while other decreasing trends did not start until the late 1970s. Trends in April 1 SWE at snow courses ranged from -<1 to ->4 cm/decade.

1. Honor the past: Provide a brief historical context for your work.

Snowpack monitoring in Rocky Mountain National Park began within 21 years of the park's founding, in 1936, and has been continuing every year since then. Dedicated hydrologists such as Ralph Parshall, inventor of the Parshall Flume, helped to establish and operate the early snow courses. Initially designed for current-year water-supply forecasting, the scientific legacy preserved in these long-term records provides valuable opportunities to study long-term trends in this important resource.

2. Celebrate the present: How is your work relevant to park visitors?

According to a University of Idaho visitor use study conducted in 2011, winter recreation is an important part of the visitor experience in Rocky. The most popular location in the park among winter visitors is Bear Lake, hosting 44% of winter visitors. Other popular winter recreation locations include Hidden Valley (17%) and the Colorado River Trail (9%). The most popular out-of-vehicle activity among winter visitors is snowshoeing (42%). Other popular activities include cross-country skiing (11%) and snowplay/sledding (9%).

3. Inspire the future: How might your work inform park management?

The trend toward smaller, earlier-melting seasonal snowpacks will present several challenges for park managers as well as downstream water managers, with important implications for water supply, ecological change, and management of winter recreation. Continued monitoring of the changing snowpack and its influences on these resources will be a critical task for scientists located in the park and elsewhere.

Key words: *Snowpack, trends, global warming, hydrology, snow water equivalent*

Upland Processes and Controls on September 2013 Mass Movements, Rocky Mountain National Park, CO

Annette **Patton**, Sara Rathburn (Department of Geosciences, Colorado State University), and Eric Bilderback (Geologic Resources Division, National Park Service). Corresponding author: annette.patton@colostate.edu

The extreme rainstorms that occurred in Colorado in September 2013 resulted in over 1000 mass sediment movements (Coe et al., 2014), and provide a valuable opportunity to better understand the controls on these events. Slope failures within the Front Range occurred primarily at elevations above 2600 m (Coe et al., 2014). Initial fieldwork of large debris flows indicates that flows within Rocky Mountain National Park (RMNP) initiated on all slope aspects at elevations from 2500-3000 m. The mass movements and the associated debris deposits in RMNP are of particular concern because they delivered significant sediment loads to upland streams, impacted buildings and infrastructure, and underscored the potential for ongoing hazards. Because cumulative rainfall was relatively uniform over a broad area, other site-specific controls can be analyzed independently.

Based on initial field observations completed in summer 2014, I hypothesize that: 1) dominant site-specific controls on debris flow initiation include slope geometry and subsurface topography, as colluvial hollows or subsurface depressions accumulate unconsolidated sediment; 2) multiple mass movements have occurred at Bighorn Creek since the Pleistocene. The historic Bighorn Ranger Station and other buildings are located on an old debris fan at this site; and 3) other geomorphic variables, such as fire history or land use changes, may outweigh slope characteristics in controlling mass movements.

Additional fieldwork will be completed in 2015 in order to confirm these hypotheses. This will be achieved through ground-based surveys of the 2013 deposits, analysis of geospatial data including aerial imagery, topographic data, and historic photos. Additionally, age-dates of old deposits will be obtained using dendrochronology, cosmogenic radionuclide analysis, lichenometry, radiocarbon dating and stratigraphic analysis. Synthesis of these data is intended to determine whether the 2013 mass movements were low probability events precipitated by anomalous hydroclimatic conditions, or whether they are likely to recur in the future.

1. Honor the past: Provide a brief historical context for your work.

Glaciation during the Pleistocene created the over-steepened slopes and generated much of the abundant unconsolidated sediment present in Rocky Mountain National Park today (Madole, 1998). These conditions and the periodic high-intensity rain events that occur at high elevations have resulted in many mass sediment movements on slopes throughout the Rocky Mountains. Particularly susceptible sites, such as Bighorn Creek, may have experienced multiple debris flows since the Pleistocene. However, the extensive nature of the September 2013 mass movements is rare; few events of this scale have occurred in recorded history (Godt, 2014).

2. Celebrate the present: How is your work relevant to park visitors?

Results of this research are vital to understanding how mass movements are triggered. This knowledge will facilitate increased hazard awareness and public safety. Additionally, the 2013 debris flow scars and deposits are conspicuous and widespread in the National Park. Results of this research will assist Park rangers and interpreters in increasing public understanding of the process of mass sediment movement and of the dominant controls on slope failure. An informed public is key to minimizing loss of life and property due to natural hazards.

3. Inspire the future: How might your work inform park management?

With more rain than snowfall expected to occur in large regions of the western US by the middle of this century (Klos et al., 2014), the increased potential for mass movements poses a significant hazard to people, structures, and infrastructure. Identifying locations where the hazard posed by debris flows is high, such as Bighorn Creek, will inform management plans for existing buildings and infrastructure. Better understanding of the geomorphic factors that increase debris flow risk can also be used to inform future construction and park use policies.

Key words: *Debris flows, geomorphic controls, hazards*

Trail use in Rocky Mountain National Park

David **Pettebone** (Rocky Mountain National Park). Corresponding author: david_pettebone@nps.gov

Baseline data on visitor use are essential to the planning and management of national park units. Area administrators must be knowledgeable about the levels, types, locations, and behaviors of visitor use. This study addressed this need by collecting trailhead use and trail encounter data on trails in Rocky Mountain National Park (ROMO). Automated-infrared counters were installed at trailheads and calibrated to estimate overall trailhead use during the summer months of 2012, 2013, and 2014. Similarly, Park volunteers collected trail encounter data on trails to estimate trail use density during the summer months of 2012, 2013 and 2014. Data were collected for high use trails such as the Long's Peak and Wild Basin and lower use trails such as the Finch Lake trail. Results show that trail use varies greatly among locations as well as by day of week and time of day. These data provide objective baseline conditions from which to discuss potential concerns related to visitor use, experience, and management. For example, many of ROMO's trails are in designated wilderness which prescribes that visitors have outstanding opportunities to experience solitude or primitive and unconfined recreation. These data can provide insights about how the timing of use levels influences these opportunities. Another example, Long's Peak is a very popular peak to summit but the Long's Peak trailhead also provides access to Chasm Lake and Eugenia Mine. Information about locations of visitor travel can also be teased out, to some degree, with the approaches and data collected in this study. Where visitor management issues are identified, actions can be formulated to address specific issues. The methods described in this paper can be used to monitor the results of management actions in order to gauge their efficacy.

1. Honor the past: Provide a brief historical context for your work.

ROMO has supported a relatively large body of social science work to understand various aspects of visitor use in the Park. For example, in 1983 Susan Henderson completed her Master's Thesis, "Decision Making Information for a Carrying Capacity Based Management System: A Case Study of Day-Users on Long's Peak, Rocky Mountain National Park". This and similar research developed a foundational understanding about visitor use in ROMO which current research benefits from and attempts to build upon.

2. Celebrate the present: How is your work relevant to park visitors?

Results from this study clearly demonstrate the popularity and demand for recreation opportunities in ROMO. Often, studies of this nature focus on perceived problem areas. However, the locations for this study were selected deliberately to understand the range of experiences and opportunities available in ROMO. This approach was selected to demonstrate that while there are some heavily used locations in the Park there are also sites that offer alternative opportunities.

3. Inspire the future: How might your work inform park management?

Financial support is difficult to obtain for the purpose of visitor use monitoring. As such, Park volunteers were recruited to collect these data. A benefit of this type of research is that these data are relatively intuitive to understand and collect and one important practical component of this project was to determine if volunteers could be used effectively to collect this type of data. The resounding conclusion was yes, Park volunteers were not only able but very engaged in this project. As such, Park managers should be inspired to continue active visitor use monitoring using volunteers to inform management questions/concerns.

Key words: *visitor use, day-use, recreation*

Prediction system for nitrogen deposition in Rocky Mountain National Park

Aaron J **Piña** (Colorado State University), Russ S Schumacher (Colorado State University), and Brock Faulkner (Texas A&M University). Corresponding author: apina@atmos.colostate.edu

East winds along the Colorado Front Range from both synoptic-scale fronts and mesoscale mountain-valley circulations transport pollutants such as NH_x and NO_x into Rocky Mountain National Park (RMNP). Wet deposition of fixed nitrogen from the Colorado Front Range brings large, unnatural concentrations into the park, altering biogeochemical cycles in the fragile alpine ecosystems. In this study, we focused on mitigating the transport of NH_x from agricultural sources by developing an early warning system to alert agricultural producers when a high-deposition day was possible. A forecast favoring high-deposition in RMNP would give agricultural producers the option to alter management practices that lead to high volatilization of NH_3.

For the early warning system, 5 runs of WRF-ARW v3.3.1 with varied physical parameterizations and initial conditions were used. From each run, 6-hour forward trajectories were release from 32 points in close-proximity to 4 municipalities in eastern Colorado. Multivariate kernel density estimation then utilized the endpoints of the 6-hour trajectories to detect high concentrations of advected "particles" released from the Fort Collins, Greeley, Fort Morgan, and Limon vicinities. Because some days with issued warnings did not end with high deposition in RMNP, a metric of success for this early warning system was when an issued warning verified with high concentrations of NH_4^+ in RMNP based on reports from the National Atmospheric Deposition Program's National Trend Network (NADP/NTN). Based on past case studies, the discussion will close with future ideas for improvements to the early warning system.

1. Honor the past: Provide a brief historical context for your work.

Since the introduction of human-induced reactive nitrogen (N), alpine ecosystems have become highly susceptible to changes due to atmospheric deposition. When N deposits on land or water, increased nutrient concentrations lead to changes in soil chemistry, eutrophication of lakes, and even changes in aquatic plant species composition. Nitrogen deposition in Rocky Mountain National Park (RMNP) has been monitored for over 3 decades. In the recent years, Loch Vale (in RMNP) experienced evidence of eutrophication for the first time since monitoring began—algal blooms. This work looks at the agricultural contribution to N deposition.

2. Celebrate the present: How is your work relevant to park visitors?

Ammonia/ammonium from agricultural sources has contributed greatly to the total N deposition in RMNP. The early warning system was created to help preserve the natural, fragile alpine ecosystems by helping to reduce N emissions from agricultural sources during periods in which emissions are likely to move to the Park. This project works towards allowing park visitors to enjoy the unadulterated beauty RMNP offers, such as pristine air, pure freshwater, and natural alpine ecosystems. Understanding sources, sinks, and ecological effects of N deposition will help park visitors appreciate the interactions (and differences) between the two biogeochemical landscapes of agricultural ecosystems and alpine watersheds.

3. Inspire the future: How might your work inform park management?

As part of the Nitrogen Deposition Reduction Plan, Park managers have set a resource management goal for wet deposition of 1.5 kg N/ha/yr. Current rates of deposition are almost twice the resource management level. With a long-term climatology of N deposition, we have identified key transport factors to help mitigate N deposition originating from agricultural sources in northeast Colorado. Improving understanding of how, when, and why atmospheric N deposition occurs will help Park managers reach desired resource management goals in ecosystems currently experiencing undesirable ecosystem changes due to excess nitrogen loading.

Key words: *deposition, nitrogen, upslope winds*

The Chemical Weathering of Calcium-Bearing Bedrock Minerals in the Loch Vale Watershed, Rocky Mountain National Park: Climatic Warming and Phosphorous Dynamics

Jason R. **Price** (Illinois College), Katherine Peresolak (McCormick Taylor, Inc.), Rebecca L. Brice (University of Arizona), and Karen S. Tefend (University of West Georgia). Corresponding author: jason.price@mail.ic.edu

The decomposition of minerals at the Earth's surface as rock chemically reacts with rainwater and snow-melt is termed chemical weathering. Chemical weathering consumes atmospheric CO_2 on geologic timescales and releases nutrients to ecosystems. One method for quantifying chemical weathering is the small watershed technique whereby atmospheric chemical inputs and stream chemical outputs are measured. The difference between the inputs and outputs reflects hydrobiogeochemical processes operating within the watershed. Research conducted in the Loch Vale Watershed (LVW) of Rocky Mountain National Park has utilized the small watershed technique since 1982. With a multi-decadal data set, negligible human influences, and a small undisturbed forest, the LVW is an ideal location to investigate chemical weathering. Calcium (Ca^{2+}) in LVW stream waters is attributable to the chemical weathering of the bedrock minerals oligoclase ($Ca_{0.27}Na_{0.73}Al_{1.27}Si_{2.73}O_8$), calcite ($CaCO_3$), and apatite ($Ca_5(PO_4)_3(F,Cl,OH)$). Chemical weathering rates for each Ca^{2+}-bearing mineral were calculated for eight triennia from 1984 to 2008. Oligoclase must be continuously chemically weathering in order to explain the stream water chemistry, contributing 25% of the Ca^{2+} in the stream waters. The rate of oligoclase weathering is increasing with time, likely reflecting climatic warming during the period of study. The chemical weathering of calcite and apatite is discontinuous through time. Depending on the proportion of chemical weathering attributable to sulfuric acid, calcite contributes 40-65% of the Ca^{2+} in the stream waters and apatite 10-35%. Apatite is the primary source of phosphorous to the LVW ecosystem. The flux of phosphorous attributable to apatite dissolution ranges from 13 to 47 mol ha^{-1} yr^{-1}, with the measured stream phosphate flux at the watershed outlet being only 1.1 mol ha^{-1} yr^{-1}. Algal activity in surface waters and sequestration in lake-bottom sediments likely serve as phosphate sinks. These findings underscore the importance of long-term, multi-decadal hydrogeochemical data sets for small-watershed-scale research.

1. Honor the past: Provide a brief historical context for your work.

Application of the small watershed technique at the Loch Vale watershed has previously been performed by M. Alisa Mast who initially published mineral chemical weathering rates in 1990 (Mast et al., 1990, Water Resour. Res. 26:2971-2978). Additional mineral chemical weathering rates have also been reported by Nadine Romero (1989, Unpublished M.S. Thesis, Michigan State University). It was the differences in results between these two pioneering studies that has inspired our continued work over 20 years later.

2. Celebrate the present: How is your work relevant to park visitors?

Summer visitors to Rocky Mountain National Park quickly notice the beauty of the bedrock outcroppings, the high-energy streams, and pristine lakes. Winter guests observe thick snow pack, and those who visit between seasons may recognize changes in the color of the stream waters. However, most visitors are unaware of the chemical reactions occurring when water encounters bedrock, especially regarding how these reactions are being modified as climate warms. Continued research within the Loch Vale watershed has the opportunity to educate the public on the naturally and anthropogenically influenced chemical processes operating in the alpine to subalpine ecosystem of the park.

3. Inspire the future: How might your work inform park management?

The robust suite of ecological and geological publications that present exceptional scientific research conducted at the Loch Vale watershed (LVW) demonstrates how invaluable this site is in long-term alpine to subalpine ecological research. Any land-use decisions by park managers regarding this small watershed should include consideration of its importance for on-going research. Existing and continued research at the LVW is also capable of improving the ability to predict alpine to subalpine hydrologic and ecosystem responses to environmental changes such as climatic warming. Such predictive capabilities may find application throughout the park.

Key words: *Loch Vale watershed, small watershed techniques, bedrock chemical weathering, calcium, phosphorous, climate change*

Projecting futures for the American pika, a climate indicator species, in Rocky Mountain National Park

Donelle Schwalm (Oregon State University), Clinton W. Epps (Oregon State University), Thomas J. Rodhouse (National Park Service Upper Columbia Basin Network), William B. Monahan (National Park Service Inventory and Monitoring Division), Jessica A. Castillo (Oregon State University), Chris **Ray** (University of Colorado-Boulder) and Mackenzie Jeffress (Nevada Division of Wildlife). Corresponding author: cray@colorado.edu

Presence of the American pika, or "rock rabbit", has been suggested to indicate the presence of microclimates mediated by sub-surface ice persisting under talus slopes and other rocky habitats used as shelter by many small animals. Therefore, recent predictions that the range of the American pika will contract dramatically under future climate scenarios suggest widespread loss of habitats suitable for pikas and associated species. Range contraction, however, likely depends on additional factors beyond climate. We used measures of pika movement and habitat configuration, in addition to climate-related variables, to predict the current and future occupancy of pika habitats in Rocky Mountain National Park (ROMO) and other parks in the western Unites States. In 2010-2012, we determined pika occurrence patterns in a spatially balanced, random selection of plots in each park, and collected fecal samples for genetic analysis of population structure. We modeled current and future pika occurrence using predictor variables representing effects of heat stress, cold stress, growing season and habitat connectivity. Measures of habitat connectivity were based on park-specific estimates of pika dispersal distance, and were allowed to fluctuate with pika occurrence. To generate future values of our predictor variables, we used eight climate projections combined with moderate to high carbon-forcing scenarios. Habitat connectivity was the most important predictor of pika occurrence in ROMO, followed closely by variables related to temperature. Climate change and subsequent reductions in habitat connectivity resulted in a feedback loop that exacerbated pika loss, and ROMO was one of two parks in which pikas were predicted to disappear by 2099 under some climate scenarios. Declines were not predicted for all parks, however, suggesting that many pika habitats will remain suitable and may even remain occupied where pika dispersal distances are sufficient to overcome effects of climate-mediated habitat loss.

1. Honor the past: Provide a brief historical context for your work.

The association of "pikas and permafrost" published by David Hafner in 1994 was based largely on observations of pika occurrence patterns in Rocky Mountain National Park and the surrounding Rocky Mountains over the past 100,000 years. Hafner's work characterized effects of both climate and habitat connectivity on the pika's distribution, and similar determinants were hypothesized much earlier by other notable biogeographers such as Joseph Grinnell. Our study uses current tools in genetic analysis and climate projection to forecast habitat-mediated effects of climate change and to refine our understanding of the scales and relative importance of habitat connectivity in several parks.

2. Celebrate the present: How is your work relevant to park visitors?

With funding from the National Park Service Climate Change Response Program, we have provided each park with regular briefings on our research to help park personnel interpret the study and its outcomes for the general public. We have also partnered with citizen-science programs to train volunteers in collecting data and samples for baseline and monitoring studies. In ROMO, we have trained volunteers through two programs (Volunteers in Parks and Front Range Pika Project) to follow scientific protocols for data and sample collection, engaging these park visitors in the scientific process and resource management.

3. Inspire the future: How might your work inform park management?

We have generated and mapped predictions about how the American pika will respond to climate change in several national parks. In ROMO, we predict a strong decline or – under some futures, extirpation –of pikas within the park by 2099. The spatial and temporal pattern of decline can be used to guide future monitoring and adaptive management. An important prediction is that pikas might persist where connectivity mitigates climate change, suggesting that pika habitats might be buffered from some effects of climate change. This prediction bodes well for other species that use these habitats.

Key words: *climate change, dispersal, connectivity, Ochotona princeps, species distribution, citizen science*

Grand Ditch Breach Restoration: Phase 1

Charlie **Repath** (Rocky Mountain National Park), Bryan Scott (Rocky Mountain National Park), Sara Rathburn (Colorado State University), David Cooper (Colorado State University), Ben Bobowski (Rocky Mountain National Park), Kevin Gaalaas(Rocky Mountain National Park), and Brian Verhulst(Rocky Mountain National Park). Corresponding author: charles_repath@nps.gov

The debris flow from the 2003 breach of the Grand Ditch, located in the Upper Kawuneeche Valley in Rocky Mountain National Park, resulted in the deposition of approximately 47,600 cubic yards of rocks, sediment and trees into Lulu Creek, the Upper Colorado River, and the Lulu City Wetland. This damaged upland, stream and wetland habitat. Phase 1 of restoration efforts to restore habitats damaged by the breach will begin in 2015. Objectives include: 1) collect geotechnical and geophysical data and then stabilize the steep hillside scar below the breach; 2) reconnect Colorado River to its historic, pre-2003 breach, channel by using hand labor to incise gravel bars and recreate a short channel. To prepare for Phase II of restoration, which will take place in 2016 and 2017, we will also 1) evaluate how channel realignment affects river stage, flow velocity and sediment transport through the Lulu City Wetland; 2) evaluate new channel/floodplain connectivity within the Lulu City Wetland, and whether resulting wetland hydrologic regime will support reestablishment of historic willow carr within the wetland; 3) collect baseline data along Lulu Creek to A) assess unconsolidated fine sediment storage in berms and bars to quantify sediment threat to downstream areas, B) quantify downstream sediment transport, C) map wood jams along Lulu Creek that are unstable and prone to breach, causing channel avulsions and mobilization of large amounts of fine sediment; and 4) assess revegetation planting needs for Phase 2 along Lulu Creek, the Colorado River, and in the Lulu City Wetland.

1. Honor the past: Provide a brief historical context for your work.

Grand Ditch construction was begun in 1890 and completed in 1937. The ditch diverts stream flow from streams in the Never Summer Range to the Cache La Poudre River to support agriculture in the Northern Colorado Plains. The 2003 breach of the Grand Ditch is only the most recent breach of the ditch to deposit large amounts of rock and sediment in the Upper Kawuneeche Valley.

2. Celebrate the present: How is your work relevant to park visitors?

The portion of the Upper Kawuneeche Valley impacted by the 2003 and older ditch breaches is located in ROMO, mostly in wilderness. The former town site for Lulu City and a number of trails are located in the area. The impacted area is visible from places in the Kawuneeche Valley and Trail Ridge Road. The breaches have negatively impacted scenic vistas, riparian habitat along Lulu Creek, wetland habitat in the Lulu City Wetland, and wildlife dependent on these habitats. Our work will restore habitats that are important to park visitors.

3. Inspire the future: How might your work inform park management?

A number of park partners provided input on proposed restoration during the EIS, and will continue to be involved throughout the restoration process. Implementation of the project will include a number of actions such as flying heavy equipment into and operating heavy equipment in wilderness, that usually do not meet the minimum requirements, and thus aren't usually allowed, under the Wilderness Act. The presence of the Grand Ditch through park wilderness is a reminder of the many outside factors that impact wilderness. How we address each of these challenges will inform park management.

Key words: *restoration, park management, Grand Ditch breach*

Soil amendment application after road construction alters resource availability and can benefit native over non-native species

Lindsay **Ringer** (Colorado State University), Cynthia S. Brown (CSU, Bioagricultural Sciences and Pest Management), Meagan E. Schipanski (CSU, Soil and Crop Sciences), and Victor P. Claassen (University of California, Division of Agriculture and Natural Resources). Corresponding author: ringerl@mac.com

Road construction increases plant invasion potential through altered soil resource availability. Non-native species on roadsides can serve as propagule sources, enabling invasion of native vegetation and threatening natural biodiversity. On newly constructed roadsides, we tested whether seeded native species can be favored over non-native species using soil amendments that (1) reduce available nitrogen (N), water loss, and soil temperature fluctuations (wood mulch) (2) supply organic matter and increase water holding capacity (yard waste compost), and (3) extend water and N availability (super-absorbent polymers). Soil amendments were incorporated before and mulch was applied after hydro-seeding in fall of 2013. In summer of 2014, we measured plant density and cover, and soil moisture and N. Seeded native density was significantly higher in the mulch (M) and mulch+compost (MCm) treatments mid-growing season compared with control (Ct) and compost (Cm) at 97±23, 90±26, 34±11, and 27±5 plants/m^2 (mean ± standard error), respectively. Non-seeded native density was significantly higher in the polymer (P) treatment compared to M, MCm and mulch + polymer at 15±3, 5±2.5, 4±2 and 4±3 plants/m^2, respectively. We detected no difference in density of non-native species among treatments. Soil N was highest in Cm mid-season and P and Cm late-season. After 14-21 mm of July rainfall, soil moisture was highest in MCm (27±5%) and M (20±4%), and lowest in Ct (11±4%). Although there was great variation in response to treatments among sites, soil amendments altered availability of N and water. This benefited native species, but not non-native species.

1. Honor the past: Provide a brief historical context for your work.

The natural beauty and biodiversity of Rocky Mountain National Park (RMNP) promoted its protection 100 years ago. Disturbance can encourage establishment of invasive species, which threaten this native biodiversity, part of the foundation of the ecosystems of the park. Since the early 1990's, Dr. Victor Claassen and Dr. Cynthia Brown have studied the success of restoration efforts after disturbance. A partnership between RMNP Resource Stewardship, the NPS Denver Service Center and Colorado State University was formed to learn more about how treatments that alter availability of soil resources will affect establishment of native and non-native species in RMNP.

2. Celebrate the present: How is your work relevant to park visitors?

The widening and realignment of Bear Lake Road in RMNP during 2012-13 presents an opportunity to test best management practices for revegetation of roadsides after construction. Vehicle exhaust contributes to increased nitrogen (N) deposition on nearby roadsides. N deposition is also increased through regional industrial, agricultural, and transportation sources. Increased N availability in nutrient-poor soils often favors non-native species. This research evaluates how to promote native vegetation without encouraging non-native species. Restoration practices must address increased N availability to protect native plant communities, which will promote the health of RMNP ecosystems and enhance the experience of park visitors.

3. Inspire the future: How might your work inform park management?

Management practices that encourage native plant establishment and discourage non-native establishment protect ecologically valuable habitat. Traditional methods for non-native plant control are herbicide treatment and manual removal. Soil amendments, like mulch, compost and polymer, are other restoration techniques that alter the conditions for plant growth after disturbance. The site-specific results from this study will inform future restoration activities in RMNP. The principles learned could be applicable to other parks with similar soil and climatic conditions. By presenting new methods for non-native species control, this research will help preserve and protect the native biodiversity and natural beauty of RMNP for generations to come.

Key words: *invasive species, nitrogen, N-deposition, restoration, re-vegetation, roads, soil amendments*

Piscicide Effects on Invertebrates in High Elevation Lakes and Streams: Establishing Baseline

Holly **Rogers** (US Geological Survey), James Roberts (US Geological Survey), Travis Schmidt (US Geological Survey), and Chris Kennedy (US Fish & Wildlife Service). Corresponding author: hrogers@usgs.gov

Native greenback cutthroat trout populations have declined significantly since the 1800s. Restoration of native cutthroat trout populations often requires the use of piscicides such as rotenone to remove non-native fishes before reintroduction. Rotenone interferes with fish and aquatic insect respiration and has been used in over 15 projects in Rocky Mountain National Park (ROMO). Managers and scientists have presumed that effects of rotenone on non-target organisms are short-term, but few studies have actually investigated such assumptions. Measuring the effects of rotenone on non-target organisms is key to understanding the long-term ecological consequences (e.g. on the food web) of piscicide use for fish reclamation projects.

Our objectives are to document initial changes in aquatic insect community structure after rotenone use and to determine the time necessary for recovery. Our approach is to characterize invertebrate community structure in Mirror Lake and Cascade Creek (ROMO) before and after rotenone use while simultaneously monitoring Browns Lake and outlet stream (Roosevelt National Forest) as a control. Both lake/stream networks will be sampled biannually for two years before treatment and at least three years post treatment. Invertebrate community metrics will be compared over time to assess initial changes in community structure and how long recovery takes.
In 2014, we collected the first year of pre-treatment data from both lake/stream networks. To date we have collected 60 Surber samples, 12 zooplankton tows, 12 Eckman grabs, and 9 Hester Dendy samples. Results from 2014 will serve as first year baseline data identifying unique aspects of each network and documenting pre-treatment characteristics of invertebrate community structure.

1. Honor the past: Provide a brief historical context for your work.

Many lakes and streams in ROMO were historically inhabited by greenback cutthroat trout. However, these waters have been stocked with non-native trout since 1886 and as a result, greenbacks have been displaced. The first greenback reclamation project in ROMO was in 1959 after the Fay Lakes drainage was treated with rotenone. This initial reclamation was unsuccessful at establishing a population in Fay Lakes, but the descendants were transferred to Caddis Lake and were able to reproduce.

2. Celebrate the present: How is your work relevant to park visitors?

Reclamation of greenback populations will allow visitors to enjoy native fauna of the southern Rocky Mountains. Park visitors will be able to observe native fish within their natural habitats which will enhance visitors' overall wilderness experience. The restoration of these native trout will increase opportunities for visitors to catch and observe the official state fish of Colorado. This project will also allow visitors to learn about conservation actions being taken by local and federal government entities to protect wild features on the landscape.

3. Inspire the future: How might your work inform park management?

At the completion of this project, managers will know if the benefits to one species outweigh the costs to the whole system after rotenone treatment. If we observe significant negative effects (i.e. long recovery or incomplete recovery of invertebrate communities) of rotenone, alternative treatment strategies may be necessary and could include seeding treatment systems with invertebrates from nearby systems or increased time between piscicide treatment and fish reintroduction.

Key words: *greenback cutthroat trout, trout reclamation, rotenone, non-target effects*

The Estes Valley Bear Education Task Force, A Community Collaboration to Improve Human and Bear Interactions

Kate **Rusch** (Town of Estes Park) and Mary Kay Watry (Rocky Mountain National Park). Corresponding author:krusch@estes.org

The Bear Education Task Force was formed in the fall of 2012 after community conversations identified education as one of the critical pathways for improving bear and human interactions in the Estes Valley. Core participants represent the community at large, Colorado Parks and Wildlife, Bears Are Us, Waste Management, Association for Responsible Development, League of Women Voters, YMCA of the Rockies, Rocky Mountain National Park, Estes Park Police Department, Town of Estes Park staff and its Board of Trustees.

The mission of the Bear Education Task Force is to communicate with common messages and materials to guide everyone in the Estes Valley to create a better environment for bears and other wildlife, preserving our watchable wildlife and promoting public safety. Key messages for local audiences include basic bear ecology, bear attractants and alternative solutions, trash management, discouraging bears and related tools, consequences for nuisance bears and who to call for help with bear issues.

Key outcomes of the program thus far include developing materials to raise awareness in the community (utility bill inserts, highway banner and bear video), conducting education and outreach, and developing and implementing a bear-responsible business pledge program. In addition, leveraging this groups' outreach with other local organizations has resulted in replacing many commercial and public trash/recycling containers with bear resistant models, deploying volunteers for targeted education to neighborhoods with bear activity of concern, reducing bear attractants through the Police Auxiliary patrols, and public bear-resistant container sponsorships by community members. An update on the Bear Education Task Force, its accomplishments to date and plans for 2015 will be highlighted.

1. Honor the past: Provide a brief historical context for your work.

Our response to bears since the initial settlement of the Estes Valley has vastly changed. Responses have included persecution of "dangerous" species such as bears, intentional habituation to provide "entertainment" for visitors and now a more balanced approach acknowledging that with effort bears and humans can co-exist safely in our shared habitat.

2. Celebrate the present: How is your work relevant to park visitors?

Bears readily move across jurisdictional boundaries. In order for the park to meet its objectives for bear management and human safety a collaborative approach is needed that includes other federal, state and local agencies and organizations as well as private citizens.

3. Inspire the future: How might your work inform park management?

The Bear Education Task Force provides a forum for information exchange. One of the benefits of the monthly meetings are that Colorado Parks and Wildlife, the YMCA of the Rockies, Estes Park Police Department and Rocky Mountain National Park all share the bear activity happening within their boundaries or jurisdiction. This provides the broader picture of a bear's activities, especially when these activities are of concern. The task force also actively exchanges information on other community's efforts for bear management and emerging research of interest. These ideas may be possible for the park to consider as appropriate in the future.

Key words: *bear, management, collaboration*

To Not Impede Nature: The Transition from Rustic to Modern Architecture in the National Parks as Represented by Twenty Structures at Rocky Mountain National Park, 1929–1962

Mitchell K. **Schaefer** (History, Colorado State University). Corresponding author: mitchell.schaefer@colostate.edu

This essay examines the history of twenty residential and storage units located along Sundance Circle and Ptarmigan Lane in the Beaver Meadows utility area at Rocky Mountain National Park between 1929 and 1962. It argues that the transition from rustic to modern architecture at Rocky demonstrated changing ideologies on the part of NPS officials, designers, and planners about how park structures could best blend with the surrounding natural landscape. The log cabins and rough-cut stone chimneys of the rustic style seemed appropriate for the wilderness of the national parks because they imitated their surroundings. In contrast, park planners hoped modern architecture would recede into nature through lack of embellishment. Thus, this paper argues that this transition illustrated two important aspects of NPS philosophy and American history in the twentieth century. First, this development demonstrates the Service's continuous goal of constructing objects that will not obstruct a visitor's ability to view and appreciate a natural landscape. Secondly, it supports the idea that rustic served as a precursor for modern architecture in the twentieth century. The author examined primary sources at Rocky including facility maintenance files and monthly superintendent reports to document the construction of the buildings in question and to place them within their wider historic context. This method revealed important information that park employees and other researchers can use when making decisions concerning the maintenance and care of these structures. Finally, this information will also help NPS officials and historic preservationists determine whether a building or district is eligible for inclusion on state and national historic registers.

1. Honor the past: Provide a brief historical context for your work.

During the Great Depression, President Roosevelt's New Deal programs included the Civilian Conservation Corps, which built hundreds of wood-frame quarters throughout the nation as barracks for enrollees. After World War II, NPS officials used many of those left over structures as employee residential units. Then, as visitation to the national parks increased in the late 1940s and early 1950s, NPS administrators recognized the need to the construct housing for employees who returned from the war and who operated the parks. As part of Mission 66, crews constructed residential units like some of those found on Sundance Circle at ROMO.

2. Celebrate the present: How is your work relevant to park visitors?

Park employees primarily use the residential units that this essay examines during the summer months. However, park visitors can see in these structures a transition from the rustic architectural style, which was popular in the early twentieth century, to that of the modern architecture that NPS officials used during the Mission 66 era. This essay, therefore, provides park visitors with an understanding of how national events influenced even the residential architecture of the parks.

3. Inspire the future: How might your work inform park management?

As mentioned before, this essay will provide park administrators and managers insight into the history of some of the residential units located in the park. This information will enable them to make informed decisions about the maintenance, care, and use of these structures. Furthermore, in the event that such buildings are considered for inclusion on the state or national historic registers of historic sites, this essay will assist in that research process.

Key words: *architecture, rustic, modern, Civilian Conservation Corps, Mission 66, visitation, employee housing*

Understanding and predicting meteorological conditions associated with high nitrogen deposition in Rocky Mountain National Park

Russ S. **Schumacher** (Colorado State University), Aaron Piña (Colorado State University), and Brock Faulkner (Texas A&M University). Corresponding author: russ.schumacher@colostate.edu

The transport and deposition of fixed nitrogen into Rocky Mountain National Park (RMNP) has led to alterations of fragile alpine ecosystems. Past research has found that the sources of nitrogen to RMNP are varied, including both regions west of the park (i.e., originating in the western U.S.), and east of the park. In particular, periods of easterly (upslope) flow can, under certain conditions, transport ammonia/ammonium from agricultural sources along the Front Range and eastern Colorado into the park. The purpose of this study is to analyze the meteorological conditions associated with these high-deposition time periods, as a step toward providing improved forecasts and alerts for these conditions. This research is informing the development of an "early warning system" for nitrogen deposition in RMNP, which would give agricultural producers in eastern Colorado the option to alter management practices that enhance volatilization of ammonia.

Using 20 years (1994-2013) of weekly observations of precipitation and wet deposition of inorganic nitrogen, we identified the weeks with the highest deposition at three National Atmospheric Deposition Program sites in and near RMNP. This analysis shows that weeks with high deposition are relatively rare in the fall and winter, and much more common in the spring and summer. The week with the greatest overall deposition included an upslope snowstorm in the spring of 2004, but summer rain events are also an important contributor, especially at the Beaver Meadows site. Then, using meteorological information from the NOAA North American Regional Reanalysis, we analyzed the weather conditions leading up to the period of high deposition. This analysis confirms that sustained moist upslope flow is nearly always occurring during periods of high deposition, but the details of the meteorological patterns are varied. The implications of the results for prediction of deposition will be discussed at the conference.

1. Honor the past: Provide a brief historical context for your work.

The deposition of reactive nitrogen in the park has led to changes in the biogeochemistry of fragile ecosystems over time. With decades of measurements of nitrogen deposition in RMNP, it allows for historical analyses of the conditions responsible for periods of high deposition, which is a key step toward providing accurate forecasts and ultimately reducing nitrogen deposition.

2. Celebrate the present: How is your work relevant to park visitors?

Visitors to RMNP are able to experience a wide variety of ecosystems at a range of elevations even during a short visit. Preserving these fragile ecosystems is a vital objective to maintaining the quality and beauty of the park for future visitors. One effort to maintain these ecosystems that this research contributes to is to reduce the deleterious effects of nitrogen deposition by understanding, predicting, and employing agricultural management practices that reduce the emission and transport of nitrogen to the park.

3. Inspire the future: How might your work inform park management?

As part of the Nitrogen Deposition Reduction Plan, Park managers have set a resource management goal for wet deposition of 1.5 kg N/ha/yr. Current rates of deposition are almost twice the resource management level. Understanding the typical meteorological conditions that lead to periods of high deposition will lead to improved predictions of these episodes, which in turn will allow park managers to collaborate with agricultural producers to encourage practices that reduce the emission and transport of nitrogen into the park.

Key words: *precipitation, nitrogen deposition, meteorology*

Proposed Limber Pine Conservation Plan for Rocky Mountain National Park

Anna **Schoettle** (USDA Forest Service, Rocky Mountain Research Station), Christy Cleaver (Colorado State University and USDA Forest Service, Rocky Mountain Research Station), Kelly Burns (USDA Forest Service, Forest Health Protection), and Jeff Connor (Rocky Mountain National Park, retired). Corresponding author: aschoettle@fs.fed.us

Limber pine (*Pinus flexilis*) is experiencing widespread mortality throughout a significant portion of its range across Western North America due to the interacting impacts of the non-native pathogen that causes the lethal disease white pine blister rust (WPBR), mountain pine beetle, dwarf mistletoe, and climate change. This keystone species is also declining in Rocky Mountain National Park from the combined effects of the severe droughts occurring since the mid-1990s and the recent mountain pine beetle outbreak. In 2010, WPBR was confirmed in the park and is expected to increase in incidence and severity, leading to long-term negative impacts on biodiversity, ecosystem processes, and park resources.

Rocky Mountain National Park, in collaboration with USDA Forest Service, began a concerted effort in 2008 to build the science foundation to facilitate efficient and effective conservation of limber pine in the park. The purpose of the limber pine conservation plan is to implement an approach to promote the resilience of limber pine stands, their ecosystem function, and biodiversity in Rocky Mountain National Park. The objectives are to: (1) conserve genetic diversity of limber pine via *in situ* and *ex situ* conservation throughout the park, (2) provide the science foundation for development of a Limber Pine Conservation Plan appropriate for the park and wilderness within the park that will sustain healthy high-elevation ecosystems, and (3) develop the park's continued important role in the Southern Rocky Mountains to preserve the genetic integrity of native flora and fauna and ensuring the future presence of limber pine by initiating and coordinating comprehensive efforts with other natural resource entities. This presentation will provide a synthesis of the current research, a discussion of its implications for management, and an introduction to a proposed Limber Pine Conservation Plan for the park.

1. Honor the past: Provide a brief historical context for your work.

Since its introduction into western North America in the early 1900's, white pine blister rust continues to spread and intensify within the ranges of susceptible hosts. Colorado and the southern Rocky Mountains are at the leading edge of the spread and are part of only a few remaining areas that contain limber pine populations with limited WPBR infection. This affords the opportunity to take a proactive approach to protect this keystone species and its ecosystems.

2. Celebrate the present: How is your work relevant to park visitors?

Limber pine is revered for its cultural significance and is a favorite tree species with park visitors. The trees are long-lived with some older than 1,000 years in the park; ancient limber pines occupy the edge of Trail Ridge Road, and a remarkable old giant stands sentinel on the shore of Lake Haiyaha. This program offers opportunities to inform and involve park visitors in the conservation of this ecologically valuable species.

3. Inspire the future: How might your work inform park management?

This program provides the scientific foundation for effective long-term limber pine management and conservation using available tools and methods compatible with the unique challenges of conservation in National Park Service mountain ecosystems.

Key words: *forest, climate change, invasives, 5-needle white pines, white pine blister rust, conservation, wilderness*

Crowding among Winter Recreationists in Rocky Mountain National Park

Jeremy **Schultz** (Eastern Washington University) and Juraj Svajda (Univerzita Mateja Bela).Corresponding author:jschultz4@ewu.edu

Crowding has been a persistent issue in outdoor recreation that still challenges recreation scholars and public lands managers. Understanding crowding can be approached from a variety of perspectives such as trends in outdoor recreation. In particular, visitation numbers in National Parks continue to be on the rise creating many situations of crowding and conflict. Considering this trend, it is important to understand why outdoor recreationists feel crowded and to learn what situational variables are affecting them.

Balancing use and user satisfaction have produced frameworks such as Limits of Acceptable Change (LAC), the Recreation Opportunity Spectrum (ROS), and carrying capacity. This study, however, was based on normative theory to help park managers understand the conditions surrounding winter recreation in Rocky Mountain National Park (RMNP) and perceptions of crowding among its users. Specifically, normative theory carries along with it items such as visitor type, visitor encounters, and situational variables.

This project included a survey of winter recreationists that was conducted from March 13th to April 6th of 2014. A visiting RMNP researcher from Slovakia collected questionnaires with the assistance of seven RMNP volunteers. There were 429 valid questionnaires completed at the Bear Lake trailhead in the park.

A multitude of variables were investigated for this study. Included in these were many of the physical and psychological conditions that showed potential to influence visitor experiences. Visitation characteristics included visitor motivation, visitation rate, group size, length of visit, activity participation, length of visit, services used in the park, and perceptions of crowding.

The results of this study give a snapshot of the demographics of winter recreationists in RMNP, summarize crowding perceptions, and describe the surrounding variables of crowding. Overall, winter recreationists at the Bear Lake Trailhead of RMNP felt little crowding during their visits. Perceptions of crowding, user groups, and visitor profiles will be used to discuss management implications.

1. Honor the past: Provide a brief historical context for your work.

Conflict in the outdoor recreation literature emerged as an area of investigation for researchers in the 1960s. As a major contributor to conflict, crowding is among the most important and actively studied issues in outdoor recreation. Continued research on crowding and conflict is continually needed as guests to National Parks are continually changing.

2. Celebrate the present: How is your work relevant to park visitors?

Many guests who visit National Parks are looking for solitude while others are driven by a desire for more collective experiences. This study offers a perspective of what winter recreationists consider to be “crowded” scenarios.

3. Inspire the future: How might your work inform park management?

Public land managers are continually challenged to balance the management of natural resources and human relations. It is a goal of this research to help managers reach higher levels of visitor satisfaction through the perspective of crowding.

Key words: *winter recreation, crowding, conflict*

Geomorphic Response of Fall River to the 2013 Flood

Mark **Schutte** (University of Colorado-Boulder), John Pitlick (University of Colorado-Boulder), Luca Rossi (University of Trento, Italy), and Roseanna Neupauer (University of Colorado-Boulder). Corresponding author: mark.schutte@colorado.edu

In Rocky Mountain National Park, the 2013 flood destabilized segments of Roaring River and deposited an unusually large amount of sand- and gravel-sized sediment near the confluence with Fall River. We initiated field studies of these two rivers in May 2014 to investigate the geomorphic response of Fall River to an increase in sediment supply. Measurements of water discharge and bed load were taken from May through August at three different locations to capture variations in sediment transport rates. Peak transport rates coincided with the peak discharge at the upstream sampling site (FR-1), but lagged behind the peak in discharge at the lower site (FR-2) by about three weeks, which is consistent with diffusive movement of sediment as observed in earlier studies. On average, 2014 transport rates were 0.003 kg/m/s and 0.035 kg/m/s at FR-1 and FR-2, respectively. Bankfull Shields stress calculations showed a slight increase across the study area, ranging from 0.0556 to 0.0571. Reference Shields stress, the non-dimensional shear stress at which sediment transport begins, remained constant across the site at 0.028. The increase in bankfull Shields stress with constant reference Shields stress and the erosion and deposition tracked by comparing cross sections measurements both indicate erosion should be expected. Continuous sediment transport rates were also calculated by scaling the continuous discharge of the Big Thompson River from a nearby USGS gage in Moraine Park. Relative to the measurements succeeding the 1982 flood, transport rates were lower than the two years immediately following the flood, but comparable to rates measured three to four years after the flood. Future work of this study will focus on understanding the differences between annual sediment loads at FR-1 and FR-2, which may be a result of the increased bankfull Shields stress or the differing effect of suspended load at these two sites.

1. Honor the past: Provide a brief historical context for your work.

In 1982, a dam break caused a catastrophic flood and severe destabilization along steep segments of Roaring River. This flood deposited large amounts of sand- and gravel- sized sediment at Roaring River's outlet into Horseshoe Park. The flood caused significant damage to parts of Old Fall River Road and the surrounding area. Soon thereafter, Fall River's response to this extreme event was documented in work throughout the 1980's by Dr. John Pitlick. This study seeks to understand how Fall River will respond to yet another extreme event: the 2013 flood.

2. Celebrate the present: How is your work relevant to park visitors?

Since the 1982 flood, the area now known as the Alluvial Fan has become an attraction to park visitors. People of all ages walk the trails alongside Roaring River up to Lawn Lake, to comprehend the powerful forces of nature depicted by the aftermath of the flood. This awe was renewed by the similar scenes produced from the 2013 flood. Old Fall River Road was once again washed out, and many parts of Roaring River eroded down to its bedrock. Understanding how Fall River will respond to these extreme events is a living lesson in geomorphology for any park visitor.

3. Inspire the future: How might your work inform park management?

Horseshoe Park and the surrounding mountains are an area of high volume traffic in Rocky Mountain National Park. When in good condition, Old Fall River Road lead directly up to the Alpine Visitor Center. Trailheads off the road lead north to beautiful backcountry hikes, and Fall River provides a myriad of fly fishing opportunities to anglers. Park management should understand how Fall River (or the many similar rivers in Rocky Mountain National Park) will respond to these extreme events, so they may make informed decisions about closures and provide accurate information to visitors hoping to visit this area.

Key words: *geomorphology, sediment transport*

Long term monitoring of an imperiled resource in Rocky Mountain NP; the vitals wetlands.

E. William **Schweiger** (Rocky Mountain I&M Network), Jim Grace (USGS), David Cooper (Colorado State University), Mike Britten (Rocky Mountain I&M Network) Laura O'Gan (Rocky Mountain I&M Network), and Erin Borgman (Rocky Mountain I&M Network). Corresponding author: billy_schweiger@nps.gov

Wetlands are iconic habitats in Rocky Mountain NP, contribute greatly to park biodiversity, and are likely useful indicators of the impacts of climate change. However, they are threatened by hydrologic and floristic modifications due to extensive historic and ongoing anthropogenic disturbances, excessive ungulate use and invasive flora. Many park wetlands require beaver for proper functioning yet this species is functionally extirpated from the park. We present results from long-term monitoring of over 150 wetland sites suggesting up to half of wetlands in the park may not be ecologically healthy (i.e. in a reference condition). This may be diminishing potential wetland contribution to the biodiversity and ecological integrity of Rocky Mountain NP overall.

We use a multimetric Index (MMI) of wetland vegetation integrity and structural equation modeling (SEM) to better estimate and understand wetland condition. MMIs are a well-established integrative bioassessment modeling tools long used by state and federal agencies that provide a synthetic score for a wetland condition based on the anthropogenic disturbance regime impacting a site. We develop novel MMIs, specific to Rocky's disturbance gradients, which account for anthropogenic and natural gradients (like elevation) that might also drive wetland condition. We use SEM to enhance our understanding of these results; SEM is increasingly being chosen by researchers as a framework for gaining causal scientific insight. Using SEM we test ideas about relationships between beaver, ungulates, and hydrology that have long been hypothesized to drive the biological integrity of wetlands in the park. Our results present new insights into how these important components of wetland ecology interact with anthropogenic disturbance and natural gradients and how these may play a role in the condition of wetlands. Results from these analyses should allow improved understanding and management of Rocky's iconic wetlands, especially as additional information is added from continued monitoring.

1. Honor the past: Provide a brief historical context for your work.

Historically, Rocky Mountain NP hydrology has been dramatically modified by both pre- and post-park establishment disturbances including building of dams, ditches, roads and other developments including a ski area and golf course. Even though many of these have been removed, there are lingering impacts exacerbated by lack of beaver, high ungulate numbers and willow pathogens which have not allowed wetlands to fully recover from historic disturbances.

2. Celebrate the present: How is your work relevant to park visitors?

To most visitors, Rocky Mountain NP riparian and wetland systems likely appear ecologically healthy and functioning properly. Our work provides an understanding of how past developments and uses, current conditions and future stresses like a rapidly changing climate have, and will continue to, affect (and often reduce) wetland integrity and function. It provides park managers and interpreters with science-based information to use in communicating with visitors and partners about the current health of the park, the need for ecological restoration of wetlands and the biodiversity and ecological services they provide.

3. Inspire the future: How might your work inform park management?

Our work provides important context and understanding of the linkages among wetland ecological characteristics and functions and the important disturbances and stressors impacting them. The MMI provides a Rocky Mountain NP specific index for monitoring wetlands over the entire park and a quantitative framework to assess the status of individual wetlands. This is also very useful in prioritizing wetlands for restoration. Through structural equation modeling, our work may provide insight into what restoration techniques and actions, e.g. removing impoundments or restoring beaver, will likely be most effective for specific restoration goals.

Key words: *monitoring, wetlands, disturbance*

The Effects of Grazing on Alpine Tundra: Intercontinental Comparison of the Rocky Mountains (Colorado, U.S.A.) and the Tatras (Slovakia, Europe)

Jozef **Šibík** (Institute of Botany Slovak Academy of Sciences), Ivana Svitková (Institute of Botany SAS) and David J. Cooper (Colorado State University). Corresponding author: jozef.sibik@savba.sk

Alpine areas are sensitive biomes that are fragile, even when the potential or real impact is not intense. Grazing can have dramatic effects on plant communities and soils in alpine ecosystems particularly within arid and semiarid regions. In this time of extreme and changing climate knowledge of how ecosystems could change is crucial for decision making to protect biodiversity for the future. Our study is aimed at determining the differences between grazed and non-grazed alpine meadows in the Rocky Mountains and Tatry Mountains (Slovakia, Europe).

A system of transects was used to inventory vascular plants of the alpine ecosystems across selected areas in the Rocky Mountains National Park as well as Tatras. Three major localities have been chosen in the alpine tundra. One has represented an area with little grazing impact, a second area has had historic grazing only, and the third have had some current grazing. We used a series of transects with 1 X 1 m plots to collect data. In each plot, several environmental features were characterized including elevation, slope, aspect terrain shape and slope position. Bedrock type and soil characteristics were noted. Certain plant traits have been observed and measured to study vegetation response to grazing.

The most important results show that total annual precipitation is crucial for regeneration after grazing impacts. Slovakian alpine communities represent a more successful model for regeneration in comparison with those in the Rocky Mts. The soil erosion in alpine areas of Colorado alpine summits still continues, even after the cessation of grazing 100 years ago, mainly due to the more arid climate conditions. Cryptogams play a significant role in enhancing surface soil stability and water infiltration. Trampling associated with grazing reduced the number of lichen species in harsh alpine habitats. Our results confirmed that recovery of disturbed alpine vegetation in the Colorado is slow.

1. Honor the past: Provide a brief historical context for your work.

Since alpine land use is possibly as old as human presence in mountain foothills we can see a large influence of alpine ecosystems for couple of hundred years. Almost all alpine vegetation types in temperate zone, especially in Europe, went through some kind of influence of anthropogenic use. Therefore, understanding the processes and the links between environmental drivers, grazing disturbance, plant functional traits, and ecosystem properties is critical for understanding long term patterns of biodiversity and ecosystem sustainability.

2. Celebrate the present: How is your work relevant to park visitors?

Recently, facing a global climate changes, it is crucial to understand how natural processes and human activities have influenced the ecosystems. This knowledge can help us to respond to coming challenges and/or help us to avoid same mistakes that were done in the past. Our comparisons show if the climate is drier in the future, the bad decision contributing to destroying alpine environment will have fatal consequences. This knowledge will provide visitors with greater insight into importance of nature conservation practices and planning not only in the Rocky Mountain NP but anywhere else in the world.

3. Inspire the future: How might your work inform park management?

Tundra vegetation that has been damaged for only a few seasons will require hundreds of years to recover. Following our results the prevention of destroying fragile environment is much efficient than restoration that is very costly when comparing with no-intervention options in the past.

Key words: *alpine communities, erosion, grazing, succession, vegetation changes*

Stability of spruce-fir forests in the Loch Vale watershed, Rocky Mountain National Park, USA

Jason **Sibold** (Colorado State University), Mary Arthur (University of Kentucky), Jill Baron (US Geological Survey), Jean Fleming (Colorado State University), and David Scott (Colorado State University). Corresponding author:scott_esser@nps.gov

Climate change in Rocky Mountain National Park will require many forest species to migrate upslope in order to track suitable climate conditions and persist into the future. For example, the lodgepole pine forest type will need to expand upslope into areas currently occupied by the Engelmann spruce-subalpine fir forest type. Whereas lodgepole extent will decrease along its current low-elevation extent, which will become ideal sites for more drought tolerant ponderosa pine and Douglas-fir, the overall extent of lodgepole pine will not change as much as the location of its distribution. In contrast, because of geomorphic limits (i.e. lack of soil development in the alpine) on upslope migration spruce-fir forests are projected to significantly decrease under warming climate. Specifically, in contrast to a range shift, spruce-fir forests are projected to retreat to isolated island patches in locations where topography buffers the impact of increasing temperatures on soil moisture availability. Sites with a combination of topographic characteristics that effectively create relatively cooler conditions as compared to the broader landscape, such as higher elevation, northerly aspect, shading from mountains, and moraines that pool cold air drainage, are likely to be places where spruce-fir forests can persist into the future. In the context of ecosystem management, identifying likely refugial sites for spruce-fir forest cover is valuable for conservation planning.

In the summer of 2013, we resampled 24 permanent plots that were originally established in 1984 in the Engelmann spruce-subalpine fir forest type of the Loch Vale watershed. Our results indicate that the spruce-fir forests in this watershed changed very little since 1984. Given the considerable changes in the spruce-fir forest type associated with the frequent drought conditions in northern Colorado over the last ca. 15 years, the topographic characteristics of the Loch Vale watershed appear to be buffering forests from regional climate.

1. Honor the past: Provide a brief historical context for your work.

Spruce-fir forests and the critical habitats that they provide have been an important component of the Rocky Mountain NP landscape for thousands of years.

2. Celebrate the present: How is your work relevant to park visitors?

This work illustrates that ecosystems will need to be dynamic in the context of rapid climate change this century. These dynamics mean that RMNP's landscape is not static and they should view the present day landscape as a snapshot that could look very different the next time they visit.

3. Inspire the future: How might your work inform park management?

Understanding which locations on the landscape are most likely to serve as refugial sites for spruce-fir forests could influence fire management decision making with the goal of protecting spruce-fir forests in locations that are critical for long-term spruce-fir persistence on the landscape.

Key words: *climate change, Engelmann spruce, subalpine fir, climate refugia*

Factors Influencing Avian Populations and Habitat Use in the Alpine Region of Rocky Mountain National Park, USA

Shelley L. **Spear** (Colorado State University, U.S. Geological Survey), Cameron L. Aldridge (Colorado State University, U.S. Geological Survey), Gregory T. Wann (Colorado State University, U.S. Geological Survey), and Clait E. Braun (Grouse, Inc.). Corresponding author: sspear@usgs.gov

Alpine environments are characterized by severe weather in high elevation areas with topographic relief that results in unique habitat for diverse assemblages of vegetation and animal species, many of which are found only in this particular ecosystem. Although alpine systems are adapted to extreme environmental conditions, like many mountain regions, climate change poses a major risk. Increases in temperature could cause upward shifts of vegetation and alter distributions of avian species in this region.

The alpine of Rocky Mountain National Park encompasses approximately one-third of the park and is home to a limited number of breeding bird species. During summer 2014, we conducted bird surveys along Trail Ridge to collect presence, absence, and abundance data for alpine bird species with a focus on American pipit, brown-capped rosy-finch, horned lark, white-crowned sparrow, and the alpine-endemic white-tailed ptarmigan. We are evaluating factors shaping bird species' distributions and abundance, and assessing habitat resources linked to population needs. Additionally, we are comparing white-tailed ptarmigan nest and brood site locations from a companion telemetry study, allowing us to evaluate habitat selection by comparing use locations to available habitat within the park's alpine ecosystem.

We present preliminary results from our first year of data collection. Combined with data collection in summer 2015, our results will serve as important baseline information for documenting future changes in alpine bird populations and habitat requirements in light of projected climate change.

1. Honor the past: Provide a brief historical context for your work.

There has been a considerable warming trend in the western U.S. in the 20th century. In lower mountain regions in particular, temperature increases in some areas are double that of the global average. With such a large portion of Rocky Mountain National Park comprised of this high mountain region, species that already have narrow geographic and temperature ranges could prove more susceptible to changes in climate or other impacts to this environment.

2. Celebrate the present: How is your work relevant to park visitors?

Trail Ridge Road provides a gateway for visitors to access this diverse and unique ecosystem and its species. Bringing recognition and awareness to the variety of species that live in or visit the alpine in Rocky Mountain National Park will offer park visitors with not only understanding, but appreciation for the important elements this ecosystem provides its inhabitants. This information can grow visitor knowledge of and support for understanding our impacts, and in collectively conserving the alpine environment and its species now and into the future.

3. Inspire the future: How might your work inform park management?

Studies involving alpine bird species' abundance and distribution in relation to certain habitat characteristics are limited. This research can not only provide a current benchmark, but also aid park managers in determining which areas or species of the alpine are more vulnerable to climate change and may need increased protection.

Key words: *alpine, breeding birds, climate change, bird abundance and distribution*

Preliminary observations on the diatom (Bacillariophyta) flora of Rocky Mountain National Park: Summary of genera present and reports of new and interesting species.

Joshua G. **Stepanek** and J. Patrick Kociolek (Department of Ecology and Evolutionary Biology and Museum of Natural History, University of Colorado). Corresponding author: patrick.kociolek@colorado.edu

Diatoms are single-celled, photosynthetic, eukaryotic microbes that form the base of the food chain in many aquatic ecosystems. Presence of certain taxa, and the composition of their communities can be powerful indicators of environmental quality and change. In an attempt to develop the first survey of diatoms from the Park, in the summer of 2014, we took samples from 114 unique locations, including the East and West sides of the Park, from elevations ranging from 8100 to 11,500 ft. A wide range of lotic and lentic environments were sampled, as well as several aerophilous habitats (spray zones from waterfalls and seeps). We provide the first detailed list of diatom genera reported from the Park. In addition, initial observations suggest there are present certain little-known or rare, previously described species, and over 40 undescribed species. We present light and scanning electron microscope observations of some of these species. The putative new species come from many different groups of diatoms, and are not limited to a specific family or genus. Further detailed studies of the diatoms of Rocky Mountain National Park will undoubtedly yield additional new species.

1. Honor the past: Provide a brief historical context for your work.

While a modest list of diatoms from Rocky Mountain National Park was generated from cores taken from lakes in the northern portion of the Park, there has been no specific survey of the diatoms. This work combines sampling efforts from monitoring work and other collections to begin to inventory these important members of the base of the food chain in aquatic ecosystems.

2. Celebrate the present: How is your work relevant to park visitors?

These microbes can tell us so much about the health of aquatic ecosystems, and they play important roles as the critical link between the abiotic and biotic worlds of these environments. The beauty of these organisms, and they many ways applications of them help visitors understand the importance of microbes.

3. Inspire the future: How might your work inform park management?

Documenting the diversity of diatoms today will help develop a baseline of information about the richness of these communities and the status and trends of water quality in the Park.

Key words: *algae, diatoms, aquatic ecosystems, new species*

Geologic, biogeomorphic, and hydrologic controls on floodplain organic carbon retention in mountainous headwater streams of the Colorado Front Range, USA

Nicholas A. **Sutfin** (Colorado State University) and Ellen E. Wohl (Colorado State University). Corresponding author: nick.sutfin@colostate.edu

Our prior work in RMNP indicates that downed large wood and soil organic carbon OC are the primary reservoirs for OC storage in mountainous headwaters streams in and around Rocky Mountain National Park. We surveyed downed large wood and floodplain soil along 24 study reaches in mountainous headwater streams of the Colorado Front Range. Comparison of study reaches with various degrees of valley confinement in old growth and younger subalpine and montane forests reveals geologic and biogeomorphic controls for OC retention. Preliminary results indicate that unconfined valley segments store much more OC per area (783 Mg/ha) compared to partly confined and confined valley segments (153 Mg/ha). Unconfined valley segments store a significant amount of OC along single thread channels and facilitate potential for development of multithread channels. Multithread channels in old-growth forests, with trees large enough to create persistent channel-spanning logjams, store relatively little sediment and a disproportionately large amount of OC as large wood. Beaver dams also facilitate the development of multithread channels and high soil OC content in beaver meadows constitutes the largest OC pools among all channel types. Preliminary reach-average radiocarbon ages from charcoal in floodplain sediment of three study reaches with drainage areas <20 km2 (1438 ± 84 yBP), 20 – 100 km2 (539 ± 110 yBP), and >100 km2 (887 ± 84 yBP) indicate that floodplain sediment turnover time is much longer in small streams at higher, subalpine elevations. Snowmelt-dominated hydrographs in these high-elevation streams rarely exhibit bimodal characteristics typical of the hydrologic disturbance regime in lower elevation montane forests of the region, which are influenced by large convective thunderstorms and monsoons of the southwestern US. The downstream cumulative effect in larger basins at lower elevation appears to be faster turnover times for floodplain sediment and associated soil OC.

1. Honor the past: Provide a brief historical context for your work.

Researchers have highlighted the potential importance of rivers in the terrestrial carbon cycle and have suggested that rivers store a significant amount of carbon within the Geosphere. Understanding OC dynamics in headwater mountainous streams provides insight into potential long-term storage and ecosystem processing of carbon in freshwater systems. Our work in relatively unaltered mountainous streams indicates that old-growth forests and beaver dams create complexity that retains carbon in mountainous streams. Thus, riparian areas have previously been unaccounted for in C stock estimates, but store 25% of the total estimated upland carbon storage within only 1% of the surface area.

2. Celebrate the present: How is your work relevant to park visitors?

Understanding the complexity of ecosystem processes in rivers and the importance of conservation will nurture increased appreciation for National Parks. Unaltered mountainous streams provide insight into natural processes and mechanisms of OC retention in riparian ecosystems. Informing park visitors about these natural riverine processes will highlight freshwater ecosystem services (e.g., filtration of surface waters, carbon sequestration) protected through conservation efforts of the National Parks and RMNP. Outreach and education to park visitors will encourage greater appreciation of unaltered mountainous streams, old-growth forest, ecosystem dynamics, and freshwater resources.

3. Inspire the future: How might your work inform park management?

Our findings support conservation of mountainous streams and old-growth forests as drivers of ecosystem services that aid in sustainability of freshwater resources and climate change. Beaver dams and logjams in old-growth forests increase channel complexity, carbon retention, natural filtration of OC in surface water, ecosystem processing, and potential long-term carbon storage. This provides insight into park management and future conditions regarding potential impact to natural riverine processes under climate change, wildfire and insect infestation. Historical decline in beaver populations has decreased potential for OC storage in RMNP. This work may inform wildlife management efforts to reintroduce beaver to RMNP.

Key words: *headwater streams, valley geometry, channel geometry, beaver, carbon, floodplain, old-growth*

Perceptions of Bark Beetle Affected Forests, Rocky Mountain National Park

Christa Cooper **Sumner** (University of Wyoming: Program in Ecology), and Jeff Lockwood (University of Wyoming, Professor of Natural Sciences & Humanities). Corresponding author: Ccoope12@uwyo.edu

This study addresses important links between science and society, including the nature of knowledge, beliefs, and aesthetic perceptions. Aesthetic experiences are one of the main ways all people interact with nature. According to an influential environmental aesthetic theory (scientific cognitivism), the greater understanding an individual has of nature, the greater their aesthetic appreciation. The Rocky Mountains have undergone a dramatic change in landscape due to the recent bark beetle outbreak. Visitors' aesthetic perceptions of the changed forest landscape as well as their knowledge of the bark beetles were explored to test the central tenet of cognitivism. In July 2013, an exploratory, mixed-methods survey was given to visitors at Many Parks Curve Overlook. Questions were grouped into four sections: 1) affective and cognitive perceptual responses; 2) harmful versus beneficial perceptions of natural or human induced environmental changes; 3) general bark beetle knowledge questions; and 4) natural versus human-caused ecological conditions (environmental viewpoint). Demographic data collected for analysis included gender, age, residence (regional vs. non-regional), and education level. Factor analysis revealed 3 underlying factors in the cognitive and affective item scales: 1) visitor expectations, 2) perceptions of forest health, and 3) perceptions of forest management. Analysis of variance showed significant relationships between gender and environmental change, education level and both environmental change and environmental viewpoint, and age and environmental viewpoint. Frequency analysis showed relatively poor bark beetle knowledge, but a strong perception of beauty. These results have implications in regard to visitor education and experiences. Limited ecological knowledge may reflect ineffective outreach to visitors. The high beauty perceptions, however, may indicate that a factor other than knowledge accounts for strong, positive aesthetic experiences despite the large amount of visible tree mortality in the forests.

1. Honor the past: Provide a brief historical context for your work.

In 1916, the Organic Act established the National Park Service (NPS) and mandated the Service to "conserve the scenery" and "provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." In clearest terms, the National Environmental Policy Act of 1969 (NEPA) calls on the Federal Government to "assure for all Americans safe, healthful, productive, and aesthetically and culturally pleasing surroundings." An ethic encoded in the governing principles of our Parks (i.e., the protection of public enjoyment, including aesthetics) can conflict with conserving natural processes.

2. Celebrate the present: How is your work relevant to park visitors?

The forest landscape of Rocky Mountain National Park has dramatically changed over the course of the bark beetle outbreak. High tree mortality is visible from the roadside and viewsheds. Forests of gray lodgepole pines contrast with postcard images of lush, green mountainsides. Visitors expecting the latter may be shocked, dismayed, or worried at the sight. Environmental aesthetic theory argues that knowledge of natural processes can intercede, resulting in an aesthetic appreciation of a less picturesque landscape. Understanding visitor perceptions and beliefs can inform Park management and be used to enhance visitor experiences in an aesthetically challenging and ecologically dynamic landscape.

3. Inspire the future: How might your work inform park management?

The bridge between science and society is often provided through education, awareness and outreach; however, a better understanding of visitor knowledge, perceptions, and beliefs is needed to provide more effective communication channels and increase awareness. Additionally, factors other than knowledge influence visitor experiences. Identifying these factors will allow Park managers to focus efforts on enhancing visitors' experiences in multiple areas. This understanding of the public will allow the NPS to sustainably manage ecological systems while still providing an enriching experience for visitors. Complemented by knowledge, aesthetic experience can provide an intrinsic means to connecting visitors with nature.

Key words: *visitor perceptions, bark beetles, environmental aesthetics, scientific cognitivism*

Know Your AQ: citizen-science air pollution monitoring & air quality education in Rocky Mountain National Park

Jennifer **Taylor** (CIRES Education Outreach-University of Colorado at Boulder), Susan Buhr Sullivan (CIRES) Alison Rockwell (NCAR), and Julia Lee-Taylor (NCAR). Corresponding author: Jennifer.L.Taylor@colorado.edu

Know Your AQ is an education outreach project coordinated by the University of Colorado's Cooperative Institute for Research in Environmental Sciences Education Outreach group (CIRES EO) in support of the joint NASA DISCOVER-AQ and NCAR FRAPPE regional air quality campaign, which ran from July 16 to August 16, 2014. CIRES staff collaborated with NCAR staff, scientists and interns to conduct a month-long series or air monitoring hikes to collect data on ground-level ozone, nitrogen oxides, and other air pollutants in natural environments of the campaign area. Staff from RMNP and the CDRLC met with the research group to provide a deeper understanding of air quality issues and research in the park. Over the four-week campaign period, weekly air monitoring hikes were conducted from trailhead to tundra in RMNP using CairClips and M-Pods (mobile personal air pollution monitors). The main objective was to collect air quality data along an East-West transect and from low to high elevations along the eastside of the park, which is most impacted by upslope air pollution. The air monitoring hike locations included the Ute Trail (adapted to driving Trail Ridge Road due to thunderstorms), Twin Sisters Trailhead to the West Summit (ended early due to thunderstorms), Bear Lake to Flattop Mountain, and Longs Peak Trailhead to Chasm Lake. In addition, twice weekly citizen-science air monitoring hikes were conducted in Boulder Open Space and Mountain Parks. To promote air quality education, CIRES and UCAR/NCAR co-hosted an educator workshop held on August 6-7 for area teachers. CIRES is developing a regionally specific air quality curriculum incorporating air quality campaign data. One of the four curriculum modules focuses on the causes and effects of Nitrogen deposition in Rocky Mountain National Park. Existing NPS air quality resources are being integrated to create this classroom-ready educational resource for educators and students.

1. Honor the past: Provide a brief historical context for your work.

Rocky Mountain National Park (RMNP) has Class 1 designation under the Clean Air Act, the highest protection afforded by law. RMNP is impacted by Front Range upslope air pollution events, especially nitrogen deposition from agricultural ammonia emissions and vehicle nitrogen dioxide emissions and ground-level ozone. In 2007, the EPA endorsed the parks Nitrogen Deposition Reduction Plan, which did not achieve its 2012 milestone goal. Elevated ozone levels are known to affect seven plant species in RMNP. Research conducted from 2006 to 2010 showed persistent ozone injury to plants. During the 2013 summer season, the park issued six ozone advisories.

2. Celebrate the present: How is your work relevant to park visitors?

Good air quality is essential for all park visitors - from enjoying clear vistas of mountains to having a healthy hike. Know Your AQ offered a unique opportunity for five NCAR REU (Research Experiences for Undergraduates) and SOARS (Significant Opportunities in Atmospheric Research and Science) interns to conduct scientific research in RMNP. This was the interns' first experience visiting a national park and being in the mountains. During the air monitoring hikes, staff and interns engaged in informal education with other park visitors on the trail by explaining the importance of good air quality and the monitoring instrumentation and methods.

3. Inspire the future: How might your work inform park management?

This project is an initial effort to directly involve park visitors in real-time monitoring of RMNP's air quality. There is potential to expand air quality data collection efforts throughout the park by offering visitors the opportunity to wear a personal ozone monitor (POM), checked out from visitor centers, while hiking along the park's many miles of trails. This data can provide a valuable and broader perspective of air quality in different locations and times in the park. This information can also supplement existing air quality monitoring efforts in order to inform further resource management of Rocky Mountain National Park.

Key words: *citizen-science outreach, air quality education, air pollution monitoring, nitrogen deposition, ground-level ozone pollution*

Rare Earth Element Enriched Pegmatite in Rocky Mountain National Park

Buck **Unsderfer** (Metropolitan State University of Denver). Corresponding author: unsderfe@msudenver.edu

The research in this study is an examination of a potential rare earth element (REE) enriched pegmatite unit in Rocky Mountain National Park. Rare earth element enriched pegmatites are coarse grained igneous rocks composed almost entirely of crystals greater than one centimeter in diameter that contain high concentrations of lanthanide elements. These REE enriched pegmatite units occur throughout Northern Colorado, specifically in Jefferson and Boulder Counties.

In the summer of 2014, rock samples were collected roughly 2 miles south of the Alpine Visitors Center near the headwaters of the Big Thompson River. The location of this study is of specific interest due to the similar geologic conditions it shares with other REE enriched pegmatites in the region. Data collected during an ICP-MS (Inductivity Coupled Plasma-Mass Spectrometer) analysis of samples in the study area show elevated levels of REEs in the pegmatite. The ICP-MS data paired with geochemical comparisons with other REE enriched pegmatites suggest the pegmatite investigated in this study may contain a possible rare earth element deposit.

1. Honor the past: Provide a brief historical context for your work.

Geology has always been an important part of Rocky Mountain National Park. Some of the most wonderful and magnificent parts of the park are its geologic features. The first geologic map of Rocky Mountain National Park was created in 1990 by Dr. William A. Braddock and James C. Cole. Since the construction of this map, many geologic discoveries have been made in the park due to research work by undergraduate students. I would like to continue adding to the research with this project.

2. Celebrate the present: How is your work relevant to park visitors?

Park visitors have always been drawn to Rocky Mountain National Park by its geologic landscapes. It is not only important to understand the geologic features which the park goers can see but also, the geologic features which are unseen. This study can be used to help the average park visitor understand what kind of geologic processes happen right under their feet. Something that they may be walking on could have particular significance to how the whole ecosystem of the park works.

3. Inspire the future: How might your work inform park management?

Uranium, thorium and heavy metals are commonly associated with the mineralization of rare earth element enriched pegmatites. When weathering of a rare earth element enriched pegmatite occurs it is possible for these harmful elements to get into soil and water. It is good for park management to be aware of high concentrations of uranium, thorium, and heavy metals so that potentially dangerous levels of these elements can be monitored.

Key words: *geology; rare earth element; pegmatite; Big Thompson River*

NO PARK IS AN ISLAND – Community collaboration

Rebecca **Urquhart** (Association for Responsible Development, Past President, Estes Valley Land Trust). Corresponding author:Rebecca.l.urquhart@gmail.com

Most National Parks, including Rocky Mountain National Park, are increasingly surrounded by development and ever burgeoning human interactions from visitors. The wildlife boundaries in our reserves rarely match the habitat of the species of the area.

The necessity for protecting wildlife corridors and reserve buffers have been widely recognized by scientist in recent years, but the Estes Park and Grand Lake communities have instinctively understood this need, almost from the dates of the formation of the Park.

The presentation will detail the history collaboration of several community organizations in expanding the boundaries and protecting and preserving buffers over decades. Projects coordinated or partnered with, for example, the Rocky Mountain Conservancy, the Colorado Conservation Fund, Estes Valley Parks and Recreation District, the Towns of Estes Park, Grand Lake & Boulder, Grand County, Boulder County, the League of Women Voters, and individual community members have supported projects to protect areas in and out of the Park. protected acreage in and out of the Park. Acquisition of the Lily Lake water rights and conservation easements restrictions bordering the Park by land trusts such as the MacGregor Ranch Trust, Estes Valley Land Trust, and the Rocky Mountain Conservancy have greatly expanding the effective preservation areas.

In additional to historical facts, the presentation will incorporate some review of the science of habitat maintenance. This topic addresses present and future values of areas of restricted use or limited development, establishing reduced use zones for animals to come and go from leave the parks for food or breeding. There will be consideration of whether protected lands without all the restrictions of national parks or wildlife refuges, open at time to hunters and recreationists, loggers and hunters will contribute to wise management of resources, human and wildlife balance, or expansion of ecological diversity.

Discussion of how such policies and practices may insure preservation of beauty and resources of the National Parks for years to come will be included in the themes, and what additional plans for expansion the Park has in place.

1. Honor the past: Provide a brief historical context for your work.

The partnerships and collaborations of individuals and organizations with the Park since its formation will be reviewed. Particular projects implemented to expand or protect Park borders and buffers implemented over decades, will be specifically described.

2. Celebrate the present: How is your work relevant to park visitors?

It will review the value of the collaboration efforts on scenic approaches to and in the Park, the preservation of the ecology and wildlife habitat and sustainability. Included will be discussion of how the completed projects have enhanced recreational opportunities in and around the Park.

3. Inspire the future: How might your work inform park management?

The current and evolving science demonstrating the necessity of reducing development and protecting areas around the Park will be emphasized. The details of the elaborate volunteer efforts and financial contributions of disparate groups of organizations and people with the common goal of protecting the Park and environs by their concerted efforts should inspire future endeavors.

Key words: *buffers, boundaries, habitat, wildlife, human, collaboration*

The Democracy of Nature: The Public Responds to Elk Culling in Rocky Mountain National Park.

Dane **Vanhoozer** (Colorado State University). Corresponding author: dmvanhoo@colostate.edu

Elk culling in Rocky Mountain National Park (ROMO) is a recurring historical issue. This paper places elk management within the broader context of the struggle to simultaneously manage for wilderness integrity and public enjoyment of national parks. It assesses the dynamics of managing for divergent objectives in light of the array of public responses to the Elk and Vegetation Management Plan (EVMP). A historical analysis of these responses offers ROMO a useful tool with which to foster constructive public participation in future management decisions.

Americans identify with the democratic establishment of national parks as a grand cultural achievement of their nation. Naturalness in parks is prized; therefore, the public scrutinizes their management. Yet, no uniform definition of naturalness exists. The 1964 Wilderness Act failed to define naturalness, though it ascribed various values to it. No consensus exists on how to manage naturalness. Some Americans insists naturalness exists where humans are absent. Others emphasize historic fidelity where nature appears and functions as it did historically.

Due to these conflicting definitions, ROMO faces problems in managing ungulates. The extirpation of predators that winnowed elk and affected their behavior resulted in overpopulation. Foraging of aspens and willows then damaged park biodiversity. The EVMP reveals the tensions of managing wilderness. Preserving certain components of naturalness means other aspects are violated. For ROMO, this means culling elk to preserve the long-term ecological services provided by aspen and willow. Policy makers adopted the EVMP to finesse their intervention. They highlighted public comment and deliberation in creating the plan as evidence of the NPS's commitment to democratic management. The EVMP strives to achieve objectives and compromise palatable to the public who venerate national parks. This history provides ROMO with a valuable record and management tool as it confronts the challenges of park stewardship in the 21st century.

1. Honor the past: Provide a brief historical context for your work.

This paper examines ROMO's historic issue of elk management. It places elk culling within the broader context of NPS's struggle to preserve wilderness integrity and historic fidelity which increasingly demands management intervention. The reintroduction of elk and the extirpation of predators freed elk from natural checks so by 1944 their overpopulation caused ecosystem degradation. ROMO implemented culling in 1944 and 1949-1950 that resulted in the elimination of 340 elk to restore damaged ecosystems. The EVMP applies adaptive management strategies as a long-term solution to elk overpopulation, emphasizing the need to manage for ecosystems' health and not just individual species.

2. Celebrate the present: How is your work relevant to park visitors?

This research demonstrates to visitors the challenges of democratically managing national parks. It uses the tensions in the democratically developed EVMP to illustrate the issues with preserving competing definitions of naturalness that, in an age of increasing tourism and global climate change, requires management intervention that violate certain definitions of naturalness. The EVMP demonstrates the NPS's commitment to public input on management issues, evident in the plan's five alternatives, which make concessions to the full spectrum of public opinion on how to appropriately manage the elk. This history can educate visitors about the management processes that produced the EVMP.

3. Inspire the future: How might your work inform park management?

This research is important to ROMO because a comprehensive account of public response to the EVMP can inform future management decisions. It will also have applications for similar management issues within the NPS in general. It serves as a case study for how the NPS might manage its most intractable issue: preserving naturalness in an age when habitat fragmentation, global climate change, and increased tourism threaten biodiversity more than ever. An understanding of past responses can aid park managers as they re-evaluate the EVMP every five years according to its adaptive management schedule.

Key words: *elk, culling, wilderness, naturalness, democracy*

Western Mountain Streams Past and Present: the Influence of Forest Stand Age and Logjam Density on Aquatic Community Structure

Michael **Venarsky** (Colorado State University, CSU), David Walters (US Geological Survey), Ellen Wohl (CSU), Dana Winkelman (CSU), Adam Herdrich (CSU) and Bridgett Livers (CSU). Corresponding author: mvenarsky@usgs.gov

Historically, western mountain streams contained high densities of channel-spanning logjams that created large depositional areas and diverted flow among multiple stream channels. Today, the legacy of timber harvest has reduced large woody debris inputs to these streams, which in turn has reduced logjam density. Streams throughout Rocky Mountain National Park have forest stand ages ranging from <100 to >350 years old, which provides the opportunity to understand how mountain streams function under both disturbed (e.g., low logjam density) and undisturbed (e.g., high logjam density) conditions. Here, we present the preliminary results of a study that is examining the interplay among forest stand age, logjam density, and aquatic insect community structure. Organic matter storage was ~3x higher in stream reaches where logjams were present. However, the abundance and biodiversity of aquatic insects did not differ among streams. Importantly, trout population size increases with increase logjam density (see Adams talk). Thus, we believe aquatic insect community abundance was not larger in streams with higher densities of logjams because of increased consumption by the larger trout populations. Thus, these preliminary results suggest that logjams are influencing aquatic insect communities by modifying predator-prey interactions.

1. Honor the past: Provide a brief historical context for your work.

Streams of the southern Rocky Mountains suffer legacy effects of beaver trapping, wood removal, logging, log floating, and other activities that have greatly reduced the size and along-stream frequency of logjams. Changes to the physical structure of streams, such as the removal of large wood inputs, can cause lasting alterations because large wood inputs create logjams which are strong drivers of stream form and function. However, few studies have linked the effects of land management (e.g., logging) or disturbance to stream wood load and mountain stream ecosystem dynamics.

2. Celebrate the present: How is your work relevant to park visitors?

Rocky Mountain National Park is one of the few places in the Central Rockies that has large intact tracts of old growth forest. This work can is relevant to Park visitors as it provides a perspective on what these landscapes and streams were like prior to European settlement. Likewise these areas support unusually high trout densities, providing quality angling opportunities for visitors.

3. Inspire the future: How might your work inform park management?

Streams in old growth forests provide a template for management and ecosystem restoration. While these headwater streams are important to recreational tourism (e.g., angling) because they support populations of rainbow trout, brook trout, and brown trout. Rocky Mountain headwater streams also support the federally threatened greenback cutthroat trout and the Colorado River cutthroat trout, a “species of special concern” in Colorado. Thus, understanding how land management influences mountain stream dynamics will have broad implications, from local economies to biodiversity management.

Key words: *Old growth forest, Logjams, Stream insects, Trout, Predator-prey interactions*

Estimation of black bear density using non-invasive hair snags along Colorado's northern Front Range

Mark **Vieira**, Jerry Apker, and Jon Runge (Colorado Parks and Wildlife). Corresponding author: mark.vieira@state.co.us

During the summers of 2011-2013 we used a series of scent-baited hair snag corrals to collect black bear guard hairs. Bears were attracted to the barbwire hair snags during a 10-week period each summer using a varying combination of scent attractors and would leave a hair sample upon crossing the barbwire. Applying a mark-recapture framework to the unique genotypes obtained from the hair collection sampling allowed the estimation of summer black bear density and abundance in all 3 years across the 649 sq. km. study area. Bear density averaged across 2011-2013 was estimated to be 10 bears/100 sq. km. This is on the higher end of densities measured in recent studies in areas adjacent to the northern Front Range of Colorado. Black bear home ranges were also estimated using GPS collars deployed within the hair snag study area. This will allow for temporally and spatially-specific home range information to be incorporated into more robust density estimation models. Measured black bear densities, as well as observed harvest and non-harvest off-take rates based on known genotypes of hair snagged individuals and those obtained from all mortality sources supports population projections in the recently approved CPW black bear management plan for the northern Front Range.

1. Honor the past: Provide a brief historical context for your work.

Black bear density estimation using non-invasive genetic models is a relatively novel method in Colorado. The most recent work evaluating black bear abundance within and adjacent to RMNP was Baldwin and Bender (2012).

2. Celebrate the present: How is your work relevant to park visitors?

This work improves Colorado Parks and Wildlife bear management in the area surrounding RMNP. Given large predators movements on a landscape scale, improved data on bear abundance outside RMNP will also have direct applications inside the park and to its visitors.

3. Inspire the future: How might your work inform park management?

Data on efficacy of non-invasive genetic sampling, bear density, mortality and home range collected adjacent to RMNP should be useful to park management in population monitoring objectives within the park.

Key words: *bear, density, population monitoring*

Long-term reproductive success of white-tailed ptarmigan along Trail Ridge in Rocky Mountain National Park

Gregory T. **Wann** (Colorado State University and U.S. Geological Survey), Cameron L. Aldridge (Colorado State University and U.S. Geological Survey), Clait E. Braun (Grouse Inc.), and Sara Oyler-McCance (U.S. Geological Survey).
Corresponding author: greg.wann@colosate.edu

Mountain ecosystems are commonly cited as examples of habitats that are highly vulnerable to climate warming. Animal populations occurring in these habitats are thought to be particularly susceptible to warming due to dispersal constraints. Unfortunately, monitoring of high elevation animal populations is uncommon relative to those at lower elevations, and a great amount of uncertainty exists in how mountain populations have responded to recent warming. We used a long-term dataset available for a population of white-tailed ptarmigan to assess how reproductive success has varied since the late 1960s. From 1968 to 2000, and again from 2011 to 2012, we studied a ptarmigan population along Trail Ridge in Rocky Mountain National Park. Breeding densities were estimated in the spring using territorial surveys, and reproductive success was estimated in the summer using counts of chicks. We fit generalized linear models (GLMs) to our reproductive data using weather covariates to assess annual variation in reproduction. A body condition index was assessed for adult birds to test if habitat quality has declined at the study site. Reproductive success declined significantly over the 1968 to 2000 period and remained low in 2011 and 2012. Weather data generally correlated poorly with annual reproduction, although weather conditions occurring during the post hatching period appear to have an important role in reproductive success. Body condition of adults declined significantly from 1968 to 2000, likely in response to declining willow (Salix spp.) cover. Habitat restoration of willow should be considered to promote self-sustaining ptarmigan populations along Trail Ridge.

1. Honor the past: Provide a brief historical context for your work.

The Trail Ridge white-tailed ptarmigan population has been declining since the mid-1970s. Past modeling work of count data from the population has suggested climate warming is to blame for the decline, but biotic factors such as forage availability may be just as likely to have a role in population persistence and growth. Long-term datasets spanning multiple decades are essential sources of information that can be used by researchers and park management to identify how animal populations within the park are changing.

2. Celebrate the present: How is your work relevant to park visitors?

Trail Ridge at Rocky Mountain National Park is undoubtedly the most visited location in the country by birders and wildlife viewers wishing to view white-tailed ptarmigan. National Parks are sanctuaries for our natural resources and should provide ample viewing opportunities for the public. Efforts to protect the integrity of park resources, such as ungulate regulation (e.g., elk) to control herbivory of plants ptarmigan are dependent on, is likely to improve ptarmigan habitat. However, some large-scale processes (such as climate change) can directly affect animal populations, even when lands are protected. Ptarmigan in the park are an excellent educational tool to highlight that direct protection of lands is not always enough to protect animal populations. Actions taken outside of park boundaries (e.g., carbon emissions) are just as important.

3. Inspire the future: How might your work inform park management?

Identifying the abiotic and biotic factors responsible for the declining ptarmigan population along Trail Ridge will help park management understand factors that can be targeted for management (e.g., habitat restoration) and those that require a much larger effort (carbon reduction to slow the rate of climate warming).

Key words: *alpine, climate warming, population viability*

Improving Visitor Experience by Reducing Bear Confrontations and Property Damage in Rocky Mountain National Park

Mary Kay **Watry** and Scott Esser (Rocky Mountain National Park). Corresponding author:mwatry@nps.gov

Between 2003 and 2006 a study of black bear population demographics, habitat utilization, critical habitats and condition was undertaken in Rocky Mountain National Park (Baldwin and Bender 2007). The results were compared to a study that took place between 1985 and 1991 (Zeigenfuss 2001). Key findings related to park bear management were that bears were frequenting visitor use areas 70% as compared to 51% of the time just 20 years ago, bears were denning closer to roads and trails and had increased their use of human foods. The contemporary research also indicated that based on recent population trends the number of bears was projected to increase. These combined factors indicated that bear/human conflicts were also likely to increase.

As a result of these findings the park has implemented programs and secured funds to improve communication, education, facilities and response to bears. The primary goal is to improve visitor experience through reducing bear damage and confrontations. Specific objectives are 1) to improve visitor's knowledge of bears and change visitor behavior to reduce confrontations; and, 2) to develop facilities and responses that reduce habituation and food conditioning of bears. An update on actions to date and the change in key areas of concern including overall incidents, property damage and food rewards will be discussed.

1. Honor the past: Provide a brief historical context for your work.

Bear management has evolved since park establishment. These changes have taken place due to a variety of factors including habitat availability, number of bears and bear incidents, number of visitors and visitor's knowledge of the natural environment including how to respond to wildlife. Our current work seeks to balance increasing visitor numbers, including those who tend to be more naïve in their behavior and interaction with the natural environment with promoting and sustaining a bear population and their ecological role and function in the park.

2. Celebrate the present: How is your work relevant to park visitors?

Three of the main outcomes from this work are to provide education to visitors, improve visitor safety and improve their overall experience in the park.

3. Inspire the future: How might your work inform park management?

The current project is adaptive in that each year we review the incidents and concerns from the previous season to inform our next set of actions. We also actively participate in the Estes Valley Bear Education Task Force where incidents involving bears that frequently cross park boundaries are discussed. This broader knowledge of a bear's activities can influence management actions in the park.

Key words: *bear, management, education, visitor experience*

Storage and flux dynamics for an active beaver meadow in the North Saint Vrain Creek, Rocky Mountain National Park, CO

Pam **Wegener**, Tim Covino, Ed Hall, and Ellen Wohl (Colorado State University). Corresponding author: Pamela_wegener@colostate.edu

North American land use practices have extensively reduced retention features (i.e. beaver meadows) with implications for catchment hydrology, morphology, and biogeochemistry. Beaver meadows are low gradient multi-threaded systems formed when beaver dams promote prolonged overbank flooding and floodplain deposition of fine sediment and organic matter. Notably, beaver meadows have been demonstrated to be highly resilient to drought, floods and wildfires. While considerable research has identified local (10^0-10^2 m) influences of beaver dams on storage and flux dynamics, there is minimal information on system-scale (10^3m) effects of serial beaver impoundments. We are quantifying hydrologic and biogeochemical fluxes and dynamics across an active beaver meadow in the North Saint Vrain (NSV) Watershed, Rocky Mountain National Park, CO. Preliminary results suggest that the meadow has a moderating effect on streamflow, is highly biologically productive, and stores substantial amounts of organic matter during storm events. In addition to highlighting the potential benefits of retention features on water quality and quantity, we aim to capitalize on the meadow's mosaic of flow regimes to address relations between local retention, hydrologic connectivity, and system-scale retention. Thus, our research should provide fundamental insights into system-scale retention and bolster the science necessary to better inform beaver reintroduction as a river restoration tool.

1. Honor the past: Provide a brief historical context for your work.

Historically, beaver have played a key role in the formation of riparian wetland valleys in the Rocky Mountain NP. However, few active beaver colonies currently exist in the region. In the 19th century, extensive fur trapping reduced beaver populations to near-extinction. Today, growing elk populations continue to reduce beaver populations by diminishing willow and aspen stands, which are essential for beaver food and habitat. By better understanding the beaver meadow environment, we are effectively offering a glimpse into the park's past. As such, we can help to inform the historical context from which to inform park management strategies.

2. Celebrate the present: How is your work relevant to park visitors?

Beaver are often regarded as a keystone species; their dam-building activities modify the environment in a way that promotes terrestrial and aquatic biodiversity. The NSV beaver meadow provides important habitats for many park visitors' favorite mammals (e.g., moose, bear, and coyotes). Further, meadow pools and side-channels are excellent habitats for fish, and thus can provide important sites for recreational fishing. Respecting the ecological significance of beaver meadows is critical to maintaining the abundance and diversity of animal life that attracts visitors to, and enamors them with, the Rocky Mountain NP.

3. Inspire the future: How might your work inform park management?

The Rocky Mountain region and Rocky Mountain NP are threatened by increased frequency and severity of floods, droughts, and wildfires. Understanding the role of retention zones (e.g.. beaver meadows) in attenuating peak flows, maintaining high water tables during drought conditions, and creating effective fire breaks, is necessary to promote the watershed services these features provide and to help inform park management strategies.

Key words: *watershed science, hydrology, biogeochemical cycling, beaver meadows.*

The McGraw Conundrum: Preserving Nature and Culture in a Historic Landscape

Jaci **Wells** (Colorado State University). Corresponding author: jcwells@lamar.colostate.edu

The National Park Service has long been seen as the leader in the nation for protecting and preserving our heritage and cultural resources. However, the NPS has faced its own challenges in learning to manage these resources. Rocky Mountain National Park was established as a natural and scenic park in 1915. Naturalists strived to preserve the park as unaltered by humans and worked to restore any alterations to that of their natural environments. This philosophy came in to conflict with the preservation and protection of cultural resources when Rocky Mountain NP acquired the McGraw Ranch in 1988.

McGraw Ranch forced Rocky to re-evaluate its practice of tearing down historic homesteads and ranches in the national park for the sake of restoring and preserving the natural resources. The park had to start considering the cultural and heritage resources that had become an important part of Rocky Mountain National Park. McGraw Ranch reflects an important change in the policies of Rocky Mountain National Park regarding its management of cultural resources.

This paper draws upon the historiography of Rocky Mountain National Park, the National Park Service, and a myriad of primary sources that cover McGraw Ranch since the park acquired it in 1988 until today as the Continental Divide Research and Learning Center.

1. Honor the past: Provide a brief historical context for your work.

Homesteaded in 1884, McGraw Ranch represents the history of dude ranches and early history of the park. Park policies focused on preserving and maintaining the natural and scenic environment and often overlooked the value of the historic resources. In the 1990s, a shift occurred in these park policies that began to place more value on historic resources alongside the natural resources.

2. Celebrate the present: How is your work relevant to park visitors?

Historic resources fascinate the visitors coming in to the national parks, and Rocky Mountain is no exception. This shift in policy by Rocky Mountain NP will allow for the identification and preservation of other historic resources that can be interpreted for the public. Additionally, this paper also increases understanding of the processes involved in preserving and managing cultural resources and identifies the challenges involved.

3. Inspire the future: How might your work inform park management?

Education and awareness are critical tools in the management of a national park. This paper gives an example of what a large-scale preservation may entail and how long it could possibly take. It also highlights the importance of relationships between concurring parties involved in the management of historic and cultural resources. Additionally, it brings awareness of possible alternatives that fit multiple needs of different groups. In the case of McGraw Ranch, the park preserved an important historic site by turning it into a facility to study the natural resources in the park so that the park could increase its knowledge and adapt its management plan to manage resources.

Key words: *historic preservation, McGraw Ranch, Natural Resource Challenge*

The Implications of the Clark's Nutcracker's (*Nucifraga columbiana*) Use of Space, Foraging Behavior, and Caching Behavior for Limber Pine (*Pinus flexilis*) Metapopulation Dynamics under Multiple Disturbance Regimes

Tyler **Williams** (University of Colorado Denver) and Diana Tomback (University of Colorado Denver). Corresponding author: Tyler.2.Williams@ucdenver

Limber pine (*Pinus flexilis*) stands comprise metapopulations; i.e., regional populations composed of local populations in dynamic flux with some recently established after disturbance and others going extinct. Historically, fire and ecological succession primarily caused extinctions. We are studying how the limber pine metapopulation in Rocky Mountain National Park (RMNP) is affected by disturbance (extinction) and long distance seed dispersal (colonization) by the Clark's Nutcracker (*Nucifraga columbiana*), limber pine's primary seed disperser.

Recently, limber pine in RMNP has experienced mortality from mountain pine beetle (*Dendroctonus ponderosae*) outbreaks and wildfire. Furthermore, white pine blister rust (non-native pathogen *Cronartium ribicola*) will likely increase limber pine mortality rates within a decade. Tree losses may result in decreased nutcracker seed dispersal, with implications for RMNP limber pine persistence.

We constructed the RMNP limber pine metapopulation from GIS layers. In summer and fall, 2014, we examined factors that influence metapopulation colonization rates: 1) Cone production estimates based on distance sampling from five limber pine stands, three ponderosa pine (*Pinus ponderosa*) stands, and three Douglas-fir (*Pseudotsuga menziesii*) stands. Nutcrackers forage on the latter two conifers if seed production in limber pine is low, or after foraging on limber pine. 2) Nutcracker seed use by estimating occupancy rates. 3) Focal sampling of nutcracker seed harvest and caching behavior. In 2015 we plan to radio-track nutcrackers to collect data on their spatial use for information on metapopulation connectivity.

We will use these data to model the RMNP limber pine metapopulation's response to future tree mortality. The 2014 data indicate that limber pine and ponderosa pine seed productivity ranged from high to low throughout our study stands, while Douglas-fir productivity was low. Nutcracker visitation correlated with the more productive sites, so nutcrackers appear to be sensitive to food availability and rates of energy gain, and adjust their foraging behavior accordingly.

1. Honor the past: Provide a brief historical context for your work.

Limber pine has historically been exposed to mountain pine beetle outbreaks as well as periodic fires. If an extinction of a local population occurred, the site was quickly recolonized by nutcracker caching. However, limber pine was not historically exposed to white pine blister rust, which could cause increased local populations extinction rates and threaten metapopulation persistence.

2. Celebrate the present: How is your work relevant to park visitors?

The nutcracker-limber pine seed dispersal mutualism is a wonderful story for park visitors, illustrating how two very different species have intertwined life histories. In addition, limber pine is an aesthetically-pleasing conifer which commonly occurs at the high elevations that attract visitors. Visitors are fascinated by the krummholz form that limber pine may take—a growth form that represents conditions so harsh that it inspires wonder a tree could even survive.

3. Inspire the future: How might your work inform park management?

Our model will provide a better understanding of the relationship between limber pine and the Clark's Nutcracker, including how far the nutcrackers are dispersing seeds, and if they cache seeds within recently burned areas. The model will be used to predict the future of the limber pine metapopulation in RMNP with increasing mortality rates.

Key words: *limber pine, metapopulations, Clark's Nutcracker, white pine blister rust, mountain pine beetle*

End member mixing analysis: source contributions to Andrews Creek, Rocky Mountain National Park, USA

Sydney **Wilson** (Colorado School of Mines), Edward Stets (US Geological Survey), Kamini Singha (Colorado School of Mines), and David Clow (US Geological Survey). Corresponding author: sswilson@usgs.gov

Subalpine headwater catchments in Rocky Mountain National Park are fragile ecosystems and important sources of fresh water to Front Range communities. The well-being of these ecosystems is important to Front Range water quality and availability and heavily dependent upon snowpack depth and the duration that this water remains in storage as snowpack. Earlier snowmelt timing and warmer average air temperatures are predicted results of climate change, which leads to precipitation occurring as rain and a decrease in the water storage as snow. Runoff dynamics and the intensity of solute flushing also are expected to change in response to decreased snow pack and earlier summer rain events. Such changes are expected to influence aquatic habitats and stream chemistry. We examined two decades of major ion and water isotope data at Andrews Creek, located in the Loch Vale watershed in Rocky Mountain National Park, using end member mixing analysis to determine relative contributions of snow runoff and groundwater inputs to Andrews Creek. Decadal, cyclical patterns were found in major ion and isotope residuals and suggest climatic influence on the stream chemistry. Preliminary results show increasing influence of an end member representative of groundwater on stream water chemistry during periods of decreased precipitation in the form of rain and snow. This finding emphasizes the important connection between climate and water quality in alpine and subalpine streams. This study builds upon the Water, Energy, and Biogeochemical Budgets (WEBB) Project with the United States Geological Survey (USGS) by examining how climate variability influences the water source contributions to a subalpine stream.

1. Honor the past: Provide a brief historical context for your work.

The USGS has conducted research within the Loch Vale watershed since the 1980s. However, the USGS WEBB program has been collecting continuous stream data since 1993 with the goal of evaluating how ecosystems with a low tolerance for changes in the distribution of water and energy are affected by climate change. Some interests of the project are to understand processes that control biogeochemical budgets, water flux, and flow paths. Our research focuses primarily on historical and current water source contributions to subalpine streams by encapsulating two-decades of collected stream chemistry to examine temporal trends.

2. Celebrate the present: How is your work relevant to park visitors?

Many park visitors are not aware of the complexity and vulnerability of subalpine ecosystems to climate change. Moreover, they do not realize how much water these ecosystems supply to dense populations, such as the Front Range. Our work is relevant because it indicates that our water sources may be changing as a result of climate change. Rivers and streams within the park are also main attractions for visitors and it is important for the Park to understand how varying source contributions to headwater streams may impact future water quality and quantity in these rivers.

3. Inspire the future: How might your work inform park management?

Characterizing historical patterns of water sources to subalpine streams provides park managers with a framework to assess the wellbeing of fragile, in-stream biota, and will aid in future decisions regarding downstream water quality remediation.

Key words: *Andrews Creek, groundwater, historical stream chemistry, end member mixing analysis*

The Brief, Tumultuous Life of Logjams in Rocky Mountain National Park

Ellen **Wohl** (Colorado State University). Corresponding author:ellen.wohl@colostate.edu

Channel-spanning logjams occur on rivers throughout the park. Each jam creates a backwater area in which finer sediment and organic matter are deposited. Jams thus slow the downstream movement of water, sediment, and nutrients. The backwater at a jam provides insect and fish habitat, so the logjams increase habitat abundance and diversity within streams. By creating obstructions to flow, logjams also enhance overbank flows that spread across the floodplain, depositing fine sediment and organic matter, eroding secondary channels, and creating further aquatic and riparian habitat. Finally, jams enhance exchanges of water between the stream and the subsurface, which mediates fluctuations in water temperature, provides subsurface habitat for aquatic invertebrates, and makes nutrients such as nitrogen available to stream organisms. Understanding the spatial distribution and persistence of logjams is thus important for managing river corridors in the park.

In 2008, I tagged all of the logs in each of 5 large jams with the intent of returning each year to measure exchanges of wood (loss of existing pieces, addition of new pieces). When 3 of the jams completely disappeared within the next 2 years, I changed my strategy. In 2010, I began an annual survey of all the channel-spanning logjams on the main rivers in Wild Basin (North St. Vrain, Hunters, Cony, and Ouzel Creeks). In 2012 I added the portion of Glacier Creek between Black and Mills Lakes. Results thus far indicate that the combined effects of fluctuations through time and space in forest mortality (blowdowns, wildfires) and in peak flows (snowmelt and rainfall floods) create substantial variations in the number and size of logjams on rivers within the national park.

1. Honor the past: Provide a brief historical context for your work.

Wood has been systematically removed from rivers throughout forested regions of North America. The wilderness portions of the park, which experienced little or no timber harvest and flow regulation, provide an exception. As scientists and resource managers seek to conditions along natural river corridors, the headwaters rivers of the park provide an invaluable reference site in which to study form and process, and particularly the natural range of variability in rivers present in the absence of human manipulations. Portions of the park containing old-growth forest are particularly important because of the extreme rarity of old-growth forest throughout the world.

2. Celebrate the present: How is your work relevant to park visitors?

Most people are attracted to rivers and expect to see healthy rivers in the national park. The details of what constitutes river health and how to ensure that rivers can remain healthy are less obvious, especially in light of recent evidence that processes beyond the control of the National Park Service, such as climate change and atmospheric deposition of nitrate, are significantly affecting watersheds in the national park. The presence of individual pieces of wood and wood accumulated in logjams is critical to continued river health in the park.

3. Inspire the future: How might your work inform park management?

By quantifying levels of wood present along diverse channel segments in the park through time, this study indicates the natural range of variability in wood within river corridors. This natural range of variability can be used to constrain management targets for wood reintroduction where wood has been artificially depleted by human activities. The study also provides a larger spatial and longer temporal context for closely related research on the effects of wood on stream physical complexity (see presentation by Livers), floodplain carbon storage (presentation by Sutfin), nutrient dynamics (presentations by Day and Madinger), and animal production (presentation by Herdrich).

Key words: *rivers, instream wood, logjams*

Groundwork Denver Green Team: Exposing urban youth to opportunities within nation parks

Shane **Wright** (Groundwork Denver) and Melake Getabecha (Groundwork Denver). Corresponding Author: Shane@groundworkcolorado.org

The continued preservation of our National Parks requires there be a sustained public interest in the natural world and an understanding of its value. As more people move into cities, and more children are being raised in an urban environment, there is a growing necessity for youth exposure to the natural world, the values it holds, and the means by which it is preserved. This potential disconnect, between urban youth and conservation principles, is the issue which the partnership between Groundwork Denver (GWD) and Rocky Mountain National Park (RMNP) attempt to address.

Groundwork Denver's youth program, the Green Team, is a youth employment program which aims at encouraging urban youth to get involved with environmental stewardship and conservation careers. For over 4 years GWD has taken trips with the Green Team up to RMNP as part of our employment program. Our experiences in the park have varied from short day trips, to month-long summer internship programs. The youth we employ are majority lower-income 15-24 year-olds whose exposure to nature has been minimal. Thus, the trips to RMNP are often the first time many of our youth have visited a national park. GWD and RMNP employees witness the impact of these visits first-hand and youth often mention the park as a highlight of their GWD experience. Our relationship with RMNP gives GWD the wonderful opportunity to expose these youth to the park which provides context for the environmental work they do in Denver. At the same time, our partnership has a meaningful impact on RMNP employees. Our partnership is not only about exposing urban youth to the environmental field, it is also about exposing the environmental field to urban youth. By working along-side a group which park employees rarely deal with, the National Park Service gains a better understanding of how to engage the ever-growing urban population into national parks and thus sustain the wonderful tradition of national parks.

1. Honor the past: Provide a brief historical context for your work.

In 2009 Groundwork Denver was honored to build a direct relationship with Rocky Mountain National Park (RMNP). Working with then RMNP Deputy Director Tony Schetzle, Groundwork Denver built a three year relationship where young people from the municipal Denver area were able to work and live for a month at RMNP every summer. Work projects included but were not limited to: habitat restoration, trails, invasive species and facilities management. Many of the young people had not been to the mountains before, none the less worked for a month in the mountains. It was an experience of a lifetime.

2. Celebrate the present: How is your work relevant to park visitors?

Currently GWD and RMNP are working to build a program similar to the internship program which ended in 2012. Since then, GWD has continued exposing youth to environmental work by partnering with organizations like Produce Denver, the Forest Service, and the Rocky Mountain Arsenal. GWD also continues to make trips to RMNP for urban youth to experience a National Park. The continuation of the GWD-RMNP partnership will expand on past achievements like urban youth engagement in conservation, strong connections between RMNP and Denver, and many environmental achievements (i.e. miles of trails built, hundreds of plants salvaged, and acres of land improved).

3. Inspire the future: How might your work inform park management?

One of the unique qualities of the GWD-RMNP partnership is its ability to bridge two disconnected communities (low-income urban youth and the National Park Service). Connecting these two communities is a win-win situation; the youth gain a new appreciation for nature and the opportunities that the NPS provides and the park gains new information and insights about how they could widen the demographics of people who visit and support the park. The program is a partnership that spawns new ideas simply from interactions between different cultures (young and old, urban and rural) and a process which gets meaningful work accomplished.

Key words: *youth, urban, conservation work, environmental exposure, diversity*

For more information about the research conference or conducting research in Rocky Mountain National Park, please visit:

http://www.nps.gov/rlc/continentaldivide/index.htm

or email: romo_research@nps.gov