Rocky Mountain National Park Biennial Research Conference 2024

Challenges and Collaborations for Changing Landscapes

Photo Credits: Hiker on Green Mountain Trail after East Troublesome Fire, NPS Photo/K.Daugherty (Cover); Upper Horseshoe Cameron Peak Fire, NPS Photo/Kim Grossman (Welcome); Moose, NPS Photo (Conversation Café)

Welcome to Rocky Mountain National Park's Biennial Research Conference

Hosted by the Continental Divide Research Learning Center

This year's conference theme is *"Challenges and Collaborations for Changing Landscapes."*

Social and ecological landscapes in Rocky Mountain National Park are facing accelerated changes brought on by visitation volumes and patterns, climate change, altered fire regimes, and shifting priorities. Collaborative science between Rocky Mountain National Park and its partners is key to better understanding these challenges. Park staff and research partners work together to co-produce science to answer management questions while students, community scientists, park visitors, and volunteers play an important role in data collection. During the Biennial Research Conference, presenters will share their work on a variety of topics including wildfire recovery, stewardship of cultural resources, vegetation and forests, visitor use, wetland ecosystems, wildlife, and air and water quality. These efforts are critical in adaptively managing the incredible resources of Rocky Mountain National Park amidst change, for the enjoyment of current and future generations.

Thank you for participating in the 2024 Research Conference. We hope this event provides you with opportunities to learn, discuss, collaborate, and to develop a deeper appreciation for stewardship of our National Parks.

Paige Lambert – Science Communicator, Continental Divide Research Learning Center, Rocky Mountain National Park

Thank you to our sponsor:

Rocky Mountain Conservancy

The 2024 Rocky Mountain National Park Biennial Research Conference is made possible thanks to the support of Rocky Mountain Conservancy (and a generous donation by donors Dean and Kate Johnson).

Schedule of Events
Rocky Mountain National Park Biennial Research Conference
Challenges and Collaborations for Changing Landscapes

Wednesday March 6, 2024		
8:00 – 8:30 AM	Morning Mixer and Coffee	
Welcome		
8:30 – 8:50 AM	Gary Ingram CDRLC Staff	Conference Introduction, Land Acknowledgement, and Awards
8:50 – 9:10 AM	Scott Esser	**Keynote Address** – Navigating change in Rocky Mountain National Park: The role of science, collaboration, and new decision-support approaches
Fire Recovery in a Warming World		
9:10 – 9:20 AM	Moderator	Session Introduction
9:20 – 9:40 AM	David Clow	Dynamic water-quality responses to wildfire in Rocky Mountain National Park
9:40 – 10:00 AM	Taylor Stack	The influence of wildfire on genetic diversity of trout in Rocky Mountain headwater streams
~~10:00 – 10:20 AM~~	~~Mattie Horn~~	~~Patterns of lodgepole pine regeneration following mountain pine beetle and fire disturbance in Rocky Mountain National Park~~
10:00 – 10:30 AM	Michelle Gibbons Ann Mills	Post-Fire Recovery: Management actions to facilitate habitat regeneration
10:30 – 11:00 AM	Break	
Towards Co-Stewardship: Past, Present, Future		
11:00 – 11:05 AM	Moderator	Session Introduction
11:05 – 11:25 AM	Katelyn Mohr	Protecting archeology with fire
11:25 – 11:45 AM	Ellyn DeMuynck	Ethnographic Resources: Complex resources that require collaborative stewardship
11:45 – 12:05 PM	Kelly Dick RisingBuffalo Maybee	Indigenous Connections: Embracing people as part of the landscape
12:05 PM – 1:15 PM	Lunch	
Science for Adaptive Vegetation Management		
1:15 – 1:20 PM	Moderator	Session Introduction
1:20 – 1:40 PM	Claire Visconti	Impact of slash pile burn scars on plant community composition across a 5-year chrono sequence
1:40 – 2:00 PM	Laurel Sindewald	Limber pine seed viability and seedling survival of treeline and subalpine provenances: Trends over a high-elevation stress gradient
2:00 – 2:20 PM	Anna W. Schoettle	Proactive Limber Pine Conservation Program – Going strong after 15 years
2:20 – 2:40 PM	Break	
Collaborative Research for Visitor Use Management		
2:40 – 2:50 PM	Moderator	Session Introduction
2:50 – 3:10 PM	Noah Creany	The Timed-Entry Permit System (TEPS) in Rocky Mountain National Park: A Multi-Year Study of the effects on the Visitor Experience and Visitor Evaluations
3:10 – 3:30 PM	Ashley D'Antonio	A collaborative approach to identifying indicators and developing monitoring protocols for visitor use management
3:30 – 3:50 PM	B. Derrick Taff	Perceptions of human waste impacts in the Longs Peak area of Rocky Mountain National Park
3:50 – 4:20 PM	**Panel: Visitor Use Management at Rocky Mountain National Park** Kyle Patterson and John Hannon – Management Specialists Scott Esser – Director, Continental Divide Research Learning Center	
4:20 – 4:30 PM	Break	
4:30 – 5:30 PM	**Poster Session** The poster session is an opportunity to read about a variety of research projects and activities in the park and engage in discussion directly with the presenter. Snacks will be provided.	

Schedule of Events
Rocky Mountain National Park Biennial Research Conference
Challenges and Collaborations for Changing Landscapes

Thursday March 7, 2024		
8:00 – 8:30 AM	Morning Mixer and Coffee	
Welcome		
8:30 – 8:35 AM	CDRLC Staff	Welcome and Introduction
Facing Ecosystem Collapse: Wetlands and Stressors* *Presentations within this session are available virtually.		
8:35 – 8:40 AM	Moderator	Session Introduction
8:40 – 9:10 AM	David J. Cooper	Riparian ecosystem collapse in the Colorado River headwaters
9:10 – 9:30 AM	E. William Schweiger	Climate and water balance effects on Rocky Mountain wetland hydrology: Challenges and opportunities
9:30 – 10:00 AM	Isabel de Silva	Kawuneeche Valley Wetland Restoration
10:00 – 10:30 AM	Will Deacy	Fifteen years of the Elk and Vegetation Management Plan: Progress and emerging challenges
10:30 – 10:35 AM	Paige Lambert	Announcements
10:35 – 10:50 AM	Break	
10:55 – 11:50 AM	**Conversation Café: Moose in Rocky Mountain National Park** Join RMNP staff for structured, small-group discussions on moose and their impacts on vital wetland ecosystems. *Advanced Sign Up is Required for Participation at the Conference Registration Table*	
11:50 AM – 1:00 PM	Lunch	
Wildlife in a Changing World		
1:00 – 1:10 PM	Moderator	Session Introduction
1:10 – 1:30 PM	Kara Brunngraber	Legacy effects of historical beaver structures on the vegetative community and structure of montane riparian ecosystems
1:30 – 1:50 PM	Nicholas Parker	Exploring white-tailed ptarmigan habitat selection in Rocky Mountain National Park
1:50 – 2:10 PM	Meg Mahoney	Using genetic markers to study evolutionary mechanisms of white-tailed ptarmigan
2:10 – 2:30 PM	Amanda Kissel	Multi-decadal monitoring reveals negative visitor effects on occupancy of amphibians in Rocky Mountain National Park
2:30 – 2:50 PM	Bennett Hardy	Of toads and tolerance: Quantifying intraspecific variation in host tolerance and resistance to a lethal pathogen
2:50 – 3:10 PM	Jonathan Lewis	Management and recovery efforts of a declining population of boreal toads in Rocky Mountain National Park
3:10 – 3:30 PM	Break	
Monitoring Air and Water Quality		
3:30 – 3:40 PM	Moderator	Session Introduction
3:40 – 4:00 PM	Emmi Felker-Quinn	Evaluating ground-level ozone risks to vegetation at Rocky Mountain National Park
4:00 – 4:20 PM	Jill Baron	Marmots still don't drink coffee. What we learned from studying the contributions of human urine to Loch Vale watershed
4:20 – 4:40 PM	Jim Cheatham	Agency and industry collaboration to reduce nitrogen deposition impacts to Rocky Mountain National Park
4:40 PM	CDRLC Staff	Conference Wrap Up

Keynote Address:

Navigating Change In Rocky Mountain National Park: The Role Of Science, Collaboration, And New Decision-Support Approaches

Scott Esser, Director - Continental Divide Research Learning Center
Koren Nydick, Resource Stewardship Program Manager

Rocky Mountain National Park (RMNP) is undergoing a lot of change. A host of interacting stressors affect resources and visitor experience in different, increasingly noticeable ways. Some of these stressors have reached thresholds that have shifted ecosystems into new states, while others show us warning signs of more change to come. RMNP has a long history of using science and collaboration to study stressors, resources, and their interactions, and applying this information to help guide decisions. Our paradigms that guide decision-making also are changing, however, as climate change is making preservation of past conditions more and more difficult. NPS has been developing and testing new approaches to scenario planning, vulnerability assessment, prioritization, and the Resist-Accept-Direct (RAD) Framework to help with decision-making. It will be increasingly important for RMNP managers and collaborators to use these approaches.

Conversation Café:
Moose in Rocky Mountain National Park

Join Rocky Mountain National Park Staff for structured, small-group discussions on moose and their impacts on vital wetland ecosystems.

Advanced sign-up during on-site registration is required.

Oral Presentation Abstracts (in order of author's last name)

Poster Presentations Abstracts (in order of author's last name)

Oral Presentations

Marmots Still Don't Drink Coffee. What We Learned From Studying The Contributions Of Human Urine To Loch Vale Watershed

Jill Baron (Ecologist, U.S. Geological Survey)
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Tim Weinmann, Colorado State University;
Kirk Acharya, Sleeping Bear Dunes National Lakeshore;
Koren Nydick, Rocky Mountain National Park;
Scott Esser, Rocky Mountain National Park

Nearly 30,000 and 45,000 people hiked the 4.0 km to the Loch, the lowest lake in Loch Vale watershed (LVWS), in June–September 2019 and 2020, respectively. Many, if not all of them, went to the bathroom during their hike. We estimated the contribution of reactive nitrogen (Nr) from human urine related to intensive use by visitors in Loch Vale Watershed (LVWS). Not only does urine convey hormones, pharmaceuticals, antibiotic-resistant bacteria, and antibiotic-resistant genes to the environment, but it also contributes Nr, which contributes to loss of biodiversity and eutrophication. Reactive nitrogen (Nr) concentrations are higher than expected for mountain lakes in Rocky Mountain National Park, and for many years, high Nr concentrations have been attributed to atmospheric deposition from regional and more distant emission sources, including combustion of fossil fuels and agricultural activities. Using caffeine as a specific marker for human urine, we compared the calculated the worst-case scenario input of urine with that from wet atmospheric Nr deposition. Informal trails and informal latrine sites were mapped, and the contribution of human urine was calculated based on several assumptions, including that each visitor voided their bladder on the ground once per visit somewhere in Loch Vale. We calculated the Nr input from urine in 2019 was 2% of the annual Nr input. Most Nr in this alpine and subalpine watershed is still attributable to emissions and subsequent wet atmospheric deposition, but a 2% contribution from human waste is not insignificant. In the very broadest sense, our results document an ecological disturbance from an unprecedented level of human activity in a protected and designated wilderness area. Local solutions to this local problem could include greater outreach to visitors of public lands about the consequences of their activities and installation of latrines.

Keywords: *Alpine lakes; Human waste; Nitrogen; Leave No Trace*

Legacy Effects Of Historical Beaver Structures On The Vegetative Community And Structure Of Montane Riparian Ecosystems

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Dr. Jeremy Sueltenfuss, Colorado State University

The American beaver (*Castor canadensis*) has earned the title of "ecosystem engineer" through its ability to create and manipulate wetland dynamics by building dams and ponding portions of rivers. Previous literature suggests abandoned dams connected to the riparian system can still function in similar, but reduced, manners as to when they were maintained. However, the impacts on vegetative community structure and composition caused by historical beaver dams not connected to the current riparian system have gone primarily under-explored. Using vegetation surveys associated with the Colorado River and historical beaver dams conducted throughout the Kawuneeche Valley (KV) in Rocky Mountain National Park, this presentation will suggest ways in which historical beaver dams that are separate from the riparian system influence the surrounding vegetation, how these communities fluctuate across the valley and how this information can inform wetland management and restoration practices currently occurring within the park. Preliminary results (in progress) will be discussed during the presentation and are expected to show that areas with more historical beaver dams on the landscape will support a more robust wetland vegetative community, lowered instances of invasive species, and a richer plant community compared to parts of the KV that have little to no historical beaver dams present. These results can provide land managers with species level recommendations of potential seed sources that can benefit restoration success. More broadly, these findings improve the understanding of the current condition of the Kawuneeche Valley and may direct decision-makers on next steps in the restoration process.

Keywords: *Legacy effects; Historical beaver dams; Vegetative community composition; Wetland management*

Agency And Industry Collaboration To Reduce Nitrogen Deposition Impacts To Rocky Mountain National Park

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Kristi Morris, National Park Service Air Resources Division

Based on research at Rocky Mountain National Park (RMNP) showing that nitrogen deposition was causing ecological impacts, a resource management goal for deposition was established by the park in 2006. For almost twenty years, the NPS, State of Colorado, and EPA (the agencies) have collaborated with Colorado agricultural producers to reduce excess atmospheric nitrogen deposition causing ecological impacts in RMNP. Leadership and scientific contributions by the agencies, including researchers, RMNP, and Air Resources Division staff have made significant progress towards understanding nitrogen deposition in RMNP and laying the groundwork for needed emission reductions and management from the agricultural sector. Studies show that ammonia emissions from Colorado agricultural production and nitrogen oxide emissions from fossil fuel use are significant contributors to the excess nitrogen deposition in the park. With most sources of nitrogen oxide emissions regulated, this initiative has connected agencies with agriculture in an unconventional partnership to secure voluntary reductions and management of ammonia emissions from the agricultural sector in northeastern Colorado. Building and maintaining the partnership requires overcoming scientific and data challenges to agree on a path forward that balances the cost and benefit to both industry and the agencies. Obstacles have been overcome through relationships and mutual understanding achieved by regular communication on the science, observing guiding principles, and staying current with research that informs agricultural best practices. By early 2024, the agencies will complete a report that evaluates progress, challenges, and the path forward. While greater park protection from this partnership is not guaranteed due to the voluntary participation from agriculture, future success is dependent on continued collaboration and research.

Keywords: *Air quality; Nitrogen deposition; Agriculture*

Dynamic Water-Quality Responses To Wildfire In Rocky Mountain National Park

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Garrett Akie, U.S. Geological Survey;
Sheila Murphy, U.S. Geological Survey;
Evan Gohring, U.S. Geological Survey

In 2020, Colorado experienced the most severe wildfire season in recorded history, as drought, abundant fuel, and high winds came together to burn 625,357 acres of forest and scrubland. A study was initiated to address concerns about potential impacts to drinking water quality from mobilization of ash and sediment. The study took advantage of a wealth of pre-fire data from two adjacent basins in Rocky Mountain National Park, one of which burned (20%) while the other did not. Pre- and post-fire data included discrete sampling and high-frequency water-quality measurements using in-stream sensors. The in-stream sensors captured large, transient spikes in concentrations of nutrients, turbidity, and DOC in the burned basin that were missed by discrete sampling. Nitrate and turbidity increased by up to one and two orders of magnitude, respectively, from pre-event concentrations during storms, and DOC increased up to 3.5X. Specific conductance, base cations, SO4, Cl, NO3, and TDN all showed statistically significant increases in concentrations post-fire ($p < 0.05$), while SiO2 and DOC did not. Empirical time-series models were built using pre-fire data and applied to the post-fire period to estimate what stream chemistry would have been if there had not been a fire. Overlays of actual post-fire chemistry showed the timing and magnitude of differences in measured and “predicted” chemistry. For most solutes, post-fire concentrations were well above those expected under the “no-fire” scenario throughout the summer, and differences were greatest during storm events. Results from this study demonstrate the importance of high-frequency data for characterizing dynamic hydrochemical responses to storm events in wildfire-affected areas. Given the likelihood of more severe fires in the future, land managers, water resource providers, and the public may benefit by planning for effects of wildfires on water supplies in the coming decades.

Keywords: *Wildfire; Water quality; Chemistry*

Riparian Ecosystem Collapse In The Colorado River Headwaters

Dr. David Cooper (Colorado State University)
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E. William Schweiger, National Park Service; Jeremy Shaw, Colorado State University; Cherie Westbrook, University of Saskatchewan; Kristen Kaczynski, California State University-Chico; Hanem Abouelezz, National Park Service; Isabel Schroeter, Scott Esser, Koren Nydick, Rocky Mountain National Park; Rod Chimner, Michigan Tech University;

Riparian ecosystems provide critical habitat for plant and animal species in Rocky Mountain National Park (RMNP). The Kawuneeche Valley (KV) supports the largest riparian wetland complex in the park. We have documented the ecological collapse of the willow riparian community in the KV during the past 20-30 years. The initial ecosystem state ("beaver willow") supported extensive tall (>3-5 m) willow stands with an understory of native sedges and grasses, important for nesting migratory birds. Beaver were present and created extensive open water habitat critical to amphibians, aquatic insects, and waterfowl.

The KV has now transitioned into a new state ("elk-moose grassland") with a >90% loss of tall willows and open water habitat. Beaver have all but disappeared. Elk and more recently moose have dramatically increased. Summer air temperatures have notably increased, and precipitation marginally decreased. Stream flow on the Colorado River has been unchanged, perhaps due to high elevation systems being better buffered from the drought characteristic of the western US. Ground water has a complex response but in general has become drier with the lack of beavers lowering water tables in select areas. These changes have allowed invasion of exotic plants including European pasture grasses. Exclosures indicate that willows exposed to ungulates have continued to decline in height while protected plants now average more than 250 cm tall.

These changes led to a fundamental alteration of the structure and functioning of KV riparian ecosystems. In its current elk-moose grassland state, the ecosystem is essentially stuck, and cannot recover. A return of the beaver willow state will require significant long term reductions in large ungulate herbivory. Restoration ideally would happen before the large, old growth willows that remain on site die, and willow seed rain that can allow willow population recruitment will no longer be possible. Climate models suggest the hydrologic system may continue to collapse making restoration urgent.

Key words: *Wetlands; Willow; Ground water; Elk, Moose; Beaver; Climate change; Collapse*

The Timed-Entry Permit System (TEPS) in Rocky Mountain National Park: A Multi-Year Study of the effects on the Visitor Experience and Visitor Evaluations

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Dr. Christopher A. Monz, Professor, Utah State University

The National Park Service Organic Act of 1916 prescribes a mandate to conserve scenery, wildlife, natural and cultural resources in addition to provide the public opportunities to experience these places *in a manner that will leave them unimpaired for future generations*. This mission statement to conserve protected areas and provide opportunities for recreation use becomes an increasingly difficult balance at the intersection of a warming planet and changing climate and ever-increasing visitation to our National Parks. Overcoming this paradoxical impasse likely requires new frameworks and approaches for conservation in the Anthropocene, where the social and ecological dimensions of protected area management are inter-dependent and adaptive systems. We propose the Timed-Entry Permit System (TEPS) system is an example of these social-ecological systems approaches to visitor-use management in national parks that targets desired conditions for resource protection and visitor experience. TEPS, first implemented in 2020, provided a laboratory to study the effects moderating the flow of visitors and its effects on park traffic conditions and the quality of the visitor experience. This presentation will highlight several years of a collaborative research partnership between the RMNP Continental Divide Research Learning Center and the Recreation Ecology Lab at Utah State University, and highlight the lessons learned about TEPS that offer insights and considerations about how to sustainably manage visitor use along with park resources in an increasingly complex and changing world.

Keywords: *Social-ecological systems; Visitor-use management; Managed-access*

A Collaborative Approach To Identifying Indicators And Developing Monitoring Protocols For Visitor Use Management

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Dr. Christopher A. Monz, Professor, Utah State University;
Kira Minehart, Ph.D. Candidate, Oregon State University;
Noah Creany, Researcher, Utah State University

Monitoring resource and social conditions is essential to visitor use management. An effective monitoring strategy allows managers to evaluate whether management actions achieve desired conditions related to ecological resources and visitor experience. However, monitoring can be costly in terms of staff time and resources. Therefore, it's important to develop monitoring protocols that are not only scientifically robust, but also feasible for long-term implementation. This presentation highlights the successes of a collaborative approach for identifying visitor use management indicators and developing field methods to monitor those indicators. Rocky Mountain National Park staff worked closely with Oregon State and Utah State Universities to refine five visitor use management-related indicators to monitor and inform park management. Then, through an iterative process, park staff and researchers codeveloped monitoring protocols that could be successfully and efficiently implemented by Rocky Mountain National Park staff. Overall, the project illustrates the benefits of partnerships between park managers and academic collaborators and the steps that are essential in developing successful monitoring strategies.

Keywords: *Visitor use management; Indicators; Monitoring*

Fifteen Years Of The Elk And Vegetation Management Plan: Progress And Emerging Challenges

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Tom Hobbs, Colorado State University;
Hanem Abouelezz, National Park Service;
Linda Zeigenfuss, LZ Ecology

Due to a legacy of predator extirpation, hydrological manipulation, and an overabundant, highly concentrated regional elk (Cervus elaphus) population, Rocky Mountain National Park (RMNP) entered the 21st century with severely degraded wetlands. In 2008, RMNP began the first phase of implementing a 20-year Elk and Vegetation Management Plan (EVMP) that relied on elk culling and redistribution, fencing, and vegetation restoration methods to restore a natural range of variation in the elk population and vegetation conditions, while continuing to provide world class opportunities to view elk. In 2023, after finishing year 15 of the EVMP, we will take stock of the progress of the EVMP, the remaining challenges, and the emerging issues that threaten continued success. Annual elk population modeling based on corrected ground counts show the number of elk using the east-side core winter range in 2022-2023 was 33 (High Probability Density Interval: 17-70), way below the management target of 800 elk. This represents a dramatic shift in elk distribution in winter, as elk now move to lower elevations rather than overwinter in RMNP. The vegetation monitoring data collected through 2018 reveals strong progress towards the objectives set out in the EVMP, however, most aspen recruitment and willow growth was in fenced areas protected from herbivory. These data demonstrate that fencing is an effective tool for vegetation restoration, but also highlights the challenges of restoring vegetation across the range. Looking to the future, the introduction and spread of functionally non-native moose (Alces alces), which can eat 60 pounds of willow per day in summer, has created a new challenge for wetland recovery efforts, while the introduction of wolves in Colorado could lead to the return of a native predator to RMNP.

Keywords: *Elk; Moose; Herbivory; Wetland restoration*

Ethnographic Resources: Complex Resources That Require Collaborative Stewardship

Ellyn DeMuynck (Cultural Anthropologist, Rocky Mountain National Park)
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Ethnographic resources are a unique category of cultural resource. They are significant not only as physical reminders of the past but because they continue to sustain living cultural identities. This quality can create both challenges and opportunities for meaningful stewardship. While the management of other types of cultural resources, such as historic structures and archaeological sites, often focuses on the physical integrity of the resources, management of ethnographic resources should focus on their cultural integrity. This requires regular consultation with the communities who value these resources as culturally significant. Cultural practices and their material footprints do not exist in a vacuum. To appropriately manage ethnographic resources, they must be considered in relationship to each other and to their broader cultural landscape. And finally, though 'ethnography' generally falls under the purview of cultural anthropologists, the inclusive nature of the ethnographic resource category requires coordination and collaboration between natural and cultural resource staff. During the summer of 2023, Rocky Mountain National Park's first staff cultural anthropologists researched approximately 100 natural and cultural resources significant to the Indigenous people of what is now the park. This information gathering was one step in the development of a holistic cultural resource program at Rocky Mountain National Park. The next, and much more challenging, step is to create stewardship strategies that reckon with the unique complexities of these "ethnographic resources."

Keywords: *Cultural resources; Collaboration; Consultation*

Kawuneeche Valley Wetland Restoration

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At one time, the Kawuneeche Valley (KV), with the headwaters of the Colorado River flowing through it, was one of the most significant wetlands in Colorado at more than 8 miles long and over a half-mile wide. Unfortunately, heavy browsing by elk and moose has reduced the cover of tall willow in this part of the park by 98% since 1999 and created a community of short, unhealthy willows unsuitable for beaver and other riparian species (Cooper et al., In prep.). Without suitable food and building materials, beavers left, leading to the drying of the valley and the continued loss of tall willow stands. Obligate wetland plants are being replaced by non-native species as the valley is in the process of converting from a beaver-willow ecosystem to an elk-moose grassland. The Kawuneeche Valley Restoration Collaborative (KVRC), with RMNP as a lead, is working to reverse this trend and restore the willow-beaver ecosystem. Over the next 10-20 years, KVRC intends to increase tall willow stands, creating habitat for beavers throughout the valley. Project activities, including installation of in-stream structures and ungulate exclosure fences, planting of willows and other wetland species, and removal of non-native plants, aim to increase the water table, retain sediment, and inundate areas near the channels for the benefit of people, wildlife (primarily beaver, amphibians, and migratory birds), and the entire ecosystem. In this talk, I will detail these restoration approaches with our Beaver Creek pilot site as an example. Additionally, I will give an overview of our monitoring strategy which will form the basis for adaptive management.

Keywords: *Wetlands; Restoration; Adaptive management*

Indigenous Connections: Embracing People As Part Of The Landscape

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RisingBuffalo Maybee, Rocky Mountain National Park

Rocky Mountain National Park (Park) is dedicated to improving educational and interpretive programs at the Park in ways that are inclusive of associated Tribal Nations and that are of value to Tribal partners. In 2017 the Park partnered with the University of Colorado's Center of the American West (CAW) and the Center for Native American and Indigenous Studies (CNAIS) to develop the Indigenous Connections project in collaboration with Tribal partners. The purpose of the Indigenous Connections project is to incorporate Indigenous perspectives, including modern and ancestral uses and histories of the area, into the interpretive and educational programs. This presentation provides an update on the long-term project and discusses the challenges and opportunities associated with knowledge sharing and the development of programs that are culturally appropriate and respect Tribal sovereignty.

Keywords: *Indigenous; Tribal Nations; Education*

Evaluating Ground-Level Ozone Risks To Vegetation At Rocky Mountain National Park

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Cody Clemens, University of Colorado-Denver;
Lisa Devore, National Park Service Intermountain Region

Ground-level ozone forms in the air from human-caused air pollutants as well as emissions from natural systems. Ozone harms the health of park staff and visitors as well as the health of plants growing in parks. Despite regulatory actions taken to reduce ozone precursor pollutants, monitored ground-level ozone concentrations have remained relatively unchanged in Rocky Mountain National Park since 1988 (NPS ARD). In the summers of 2006-2010, Dr. Bob Kohut and park staff conducted surveys for ozone foliar injury in the park. They found leaf injury each summer on cutleaf coneflower (*Rudbeckia laciniata var. ampla*) populations in the park (Kohut et al 2012). In the summers of 2022 and 2023, we revisited and re-surveyed 13 locations in the park where Kohut and park staff had documented ozone injury to cutleaf coneflower. In both 2022 and 2023, surveys found multiple cutleaf coneflower populations with ozone foliar injury symptoms. In recent summers, maximum area of leaf injury on the most heavily affected cutleaf coneflower leaves exceeded the maximum leaf injury observed in 2006-2010. We present the results of the 2022 and 2023 surveys and discuss the interpretation of these results in light of current ozone concentrations and other ozone-sensitive species in the park.

Keywords: *Air quality; Ozone; Vegetation*

Post Fire Recovery: Management Actions to Facilitate Habitat Regeneration

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Ann Mills (Revegetation Lead, Rocky Mountain National Park)

In 2020, the two largest fires in Colorado's history, East Troublesome and Cameron Peak, entered Rocky Mountain National Park (RMNP), impacting 30,000 acres. While fire on the landscape is a natural recurring process, climate change and historical land use and management have altered wildfire behavior and post fire recovery. Beginning in 2021 the Resource Stewardship initiated multi-year projects to manage invasive vegetation and facilitate recovery of limber pine (*Pinus flexilis*) and wetland shrubs, specifically willow (*Salix* sp.). Ungulate browse, pathogens, and altered ecosystems have negatively impacted these species for decades and recent fires have exacerbated those impacts. Our management actions focus on directed habitat restoration with the goal of improving ecosystem function and resilience.

In recent decades, due to heavy browsing by elk and a lack of beaver activity in Moraine Park, natural willow propagation has been limited. Approximately 121 acres of Moraine Park have been fenced off as temporary elk exclosures to protect willow communities that, when healthy, provides a diverse habitat for animal and plant species. Between 2011 and 2020 several willow planting projects occurred to expedite their recovery; however, fires in 2013 and in 2020 negatively impacted those efforts. Burned Area Rehabilitation (BAR) funding was secured to implement wetland shrub planting projects in 2022-2024. Due to the funding source, planting must occur in exclosures that were burned in the 2020 East Troublesome Fire, which included those in Moraine Park and Upper Beaver Meadows.

Minimizing the establishment of exotic invasive plants in the first years following fire is also critical to promote native vegetation and habitat recovery. Since 2021, a dedicated BAR invasives crew has surveyed and treated exotic invasive plants deep within recent fire perimeters. This work prioritizes 40 miles of trail corridors, wilderness campsites, and other high traffic areas across RMNP that have elevated potential for exotic invasive seed transmission. While complete eradication of these backcountry populations is unlikely, our goal is to assist native plant regeneration by minimizing competition for light, water, and nutrient resources.

Among the native vegetation burned in 2020 were many populations of limber pine, a keystone species of the subalpine–alpine ecotone. Actions to conserve limber pine within RMNP have been ongoing since the 1950s and have encompassed a range of management strategies including monitoring and controlling the invasive fungal pathogen white pine blister rust (WPBR), minimizing pressure from mountain pine beetle outbreaks, genetic conservation through seed banking, and replanting key limber pine groves that have burned. These efforts will continue in 2024 and beyond to support the health and diversity of this foundation species.

Keywords: *Revegetation; Invasives; Burned Area Recovery; Willow; Limber Pine*

Of Toads And Tolerance: Quantifying Intraspecific Variation In Host Tolerance And Resistance To A Lethal Pathogen

Dr. Bennett Hardy (Postdoctoral Researcher, Chapman University)
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Dr. Erin Muths, U.S. Geological Survey;
Dr. W. Chris Funk, Colorado State University;
Dr. Larissa Bailey, Colorado State University

Due to the ubiquity of disease, hosts have evolved strategies of disease resistance and tolerance to defend themselves from further harm once infected. Resistance mechanisms directly limit pathogen growth while tolerance mechanisms limit the damage caused by the pathogen. Testing for intraspecific variation in host populations is important for informing decisions about captive breeding, translocation, and disease treatment. Here, we test for intraspecific variation in boreal toad (*Anaxyrus boreas boreas*) tolerance and resistance against the fungal pathogen Batrachochytrium dendrobatidis (Bd). Boreal toads have severely declined in Colorado (CO) due to Bd, but populations in western Wyoming (WY) appear to be less affected. We used a common garden experiment to expose individuals from four populations (2 in CO; 2 in WY) to Bd and monitored for two months. We used a multi-state model to estimate survival and transition probabilities between infected and cleared states to reveal the dynamic process that traditional approaches fail to capture. We found that WY toads are tolerant to Bd infection with higher survival probabilities than those in CO when infected with identical pathogen burdens. WY toads also had lower probabilities of reinfection, suggesting resistance. Our results provide new insights into the study of host defenses, how scientists measure host tolerance and resistance, and demonstrate that describing an entire species as 'tolerant' or 'resistant' is unwise without testing for intraspecific variation.

Keywords: *Amphibian declines; Conservation; Disease*

Patterns Of Lodgepole Pine Regeneration Following Mountain Pine Beetle And Fire Disturbance In Rocky Mountain National Park (Withdrawn)

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Climate-driven increases in disturbance activity from bark beetle outbreaks and wildfire has prompted concerns for potential declines in forest regeneration. In forests of the Southern Rocky Mountains, widespread tree mortality from bark beetles over the last few decades has resulted in novel forest conditions that may drive alternate patterns of recovery following subsequent fire disturbance. As such, the extreme fire season of 2020 presents a unique opportunity to examine the mechanisms by which the interactive effects from bark beetle outbreaks and fire shape trajectories of post-fire recovery and future forest resilience. In this study, we collected field data on lodgepole pine seedling recruitment following the East Troublesome fire of 2020 to evaluate whether forest changes resulting from a recent mountain pine beetle outbreak (occurring 11-20 years pre-fire) influenced patterns of post-fire regeneration. In the summer of 2022, we sampled 116 sites across gradients of beetle severity, fire severity, and stand age in Rocky Mountain National Park, Colorado. In each site, we measured canopy and surface fire severity, forest structure, and post-fire seedling densities. We found that 73% of our sites had ample regeneration densities to develop into a well-stocked lodgepole pine stand (381 – 120,752 t ha $^{-1}$), however seedling densities were highly variable between our sites. Bayesian hierarchical methods were used to determine the relative influence of canopy consumption, mountain pine beetle severity, stand characteristics, and topographic variables on post-fire lodgepole pine seedling abundance. Preliminary results show that the abundance of lodgepole pine seedlings is strongly associated with canopy cone abundance, highlighting an important mechanism by which pre-fire forest structure and canopy fire severity may influence variability in post-fire recruitment. The insights provided by this research serve to inform predictions of future forest trajectories following sequential beetle and fire disturbance and underscore a need for tailored forest management approaches that consider both the legacy of bark beetle outbreaks as well as the variable nature of fire effects.

Keywords: *Post-fire regeneration*; *Disturbance interactions*; *Mountain pine beetle*; *Lodgepole pine*

Multi-Decadal Monitoring Reveals Negative Visitor Effects On Occupancy Of Amphibians In Rocky Mountain National Park

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Determining where animals are and if they are persisting across landscapes is necessary to implement appropriate management and conservation actions. For long-lived animals and those with boom and bust life histories, perspective across time contributes to discerning temporal trends in and identifying mechanisms affecting occupancy and persistence. Long-term data are particularly useful in protected areas where change may be less obvious or occur more slowly. We used over three decades of long-term amphibian data (for *Pseudacris maculata*, *Lithobates sylvaticus* and *Ambystoma mavortium*) specific to Rocky Mountain National Park (RMNP) in a Bayesian occupancy modeling framework to estimate changes in colonization and persistence of amphibians across pre-defined catchments and explore mechanisms (e.g., precipitation, drought, visitor use) behind observed changes. Our results indicate that the probability of colonization of previously unoccupied catchments is low, and the probability of persistence is declining for all three species; and that occupied catchments are increasingly isolated. We conclude that catchments with a higher proportion of popular trails negatively affected the initial probability of occupancy, and that increasing visitor use negatively affected the probability of persistence of amphibians in catchments across RMNP. While these results are sobering, they also provide a way forward where mitigation efforts can target identified drivers.

Keywords: *Amphibians; Climate; Visitor use; Occupancy modeling*

Management and Recovery Efforts of a Declining Population of Boreal Toads in Rocky Mountain National Park

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The boreal toad (Anaxyrus boreas boreas) is one of five amphibians native to Rocky Mountain National Park which includes chorus frogs, wood frogs, tiger salamanders and the locally extirpated northern leopard frog. In 1993, boreal toads were listed as an endangered species by the state of Colorado. Batrachochytrium dendrobatidis (Bd), a fungal pathogen which causes a fatal skin disease in amphibians, has been credited as the cause of their rapid decline within the park over the past 30 years.

The Conservation Biology Program at Rocky Mountain National Park leads the effort to actively monitor and recover boreal toad populations throughout the park in collaboration and partnerships with other federal and state natural resource agencies as well as non-profits and volunteers. As an active member on the interagency Boreal Toad Conservation Team, the park participates in ongoing research and incorporates the most current practices to guide their management.

Each spring seasonal wildlife crews hike to remote areas in the park to monitor boreal toad breeding activity and conduct disease testing at historic breeding ponds. These annual surveys help to establish population trends and create long-term datasets to inform management decisions. As populations of toads at historic breeding sites are lost to disease, efforts are made to initiate new breeding sites at ponds currently free of disease. Each spring, Rocky Mountain National Park and its collaborators collect boreal toad eggs from active breeding sites. The eggs are transported out of the mountains to be reared at Colorado Parks and Wildlife hatcheries. Before the tadpoles metamorph into their terrestrial form, they are transported to the park and released into a predetermined high-quality reintroduction pond. The initiation of these reintroduction sites provides the opportunity for the boreal toads to establish in disease free ponds and begin a new self-sustaining population, which may be the key to long-term survival of the species in the park.

Keywords: *Boreal toad; Conservation; Reintroduction; Disease*

Using Genetic Markers To Study Evolutionary Mechanisms Of White-Tailed Ptarmigan

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Alpine species are among the most sensitive to climatic warming, as they already occupy the highest, coolest elevations and thus cannot shift their ranges higher to counteract rising temperatures. White-tailed ptarmigan (*Lagopus leucura*) are one such susceptible species found in alpine habitats across Colorado. To design effective conservation strategies for these animals, it is crucial to understand the evolutionary mechanisms underpinning how ptarmigan interact with their environments. Leveraging recent advances in high-throughput sequencing, we have sequenced and annotated (i.e., identified functional elements) the entire genome of the white-tailed ptarmigan. From this genome assembly, we are developing a panel of single-nucleotide polymorphisms that will be used to genotype white-tailed ptarmigan samples collected in Rocky Mountain National Park (ROMO) between 2011 and 2023. We will use these results to construct a pedigree of the ROMO white-tailed ptarmigan population, which in turn will allow us to assess rates of extra-pair paternity and post-hatch brood amalgamation, both behaviors with important implications for population dynamics and genetic structure. We will also assess genes or gene groups under selection, and, using historical white-tailed ptarmigan samples collected between the 1890s and the 2020s, examine how local adaptation has changed over time. These findings may have important implications for understanding the evolutionary trajectories of white-tailed ptarmigan and other high-altitude species, and for designing effective conservation strategies in the face of rapid environmental change.

Keywords: *Conservation genomics; Local adaptation*

Protecting Archeology With Fire

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Fire is a natural environmental phenomenon and has been an integral part of our ecosystem for millennia. The population and development of North America has repeatedly brought humans into contact with fire in all manner of circumstances including wildland fires. Indigenous peoples used fire to clear areas for crops and travel, to manage the land for specific species of both plants and animals, to hunt game, and for many other important uses. Over the past 400 years, Americans as a society have grown to fear all forms of fire and have sought ways to suppress it, especially wildland fire. By suppressing fire in fire adapted landscapes, humans have detrimentally impacted the landscape by creating unnatural fuel build up. As a result, wildland fires became more severe and often have mega fires that plague the western United States. These fires not only cause impacts to natural resources and vegetation but also impacts cultural resources. Managing cultural resources during a wildland fire event is challenging and effects can be divided into direct, indirect, and operational effects. To minimize such effects, the Fire Archeology Program in collaboration with the Fuels Program is implementing proactive measures to better protect cultural resources against fire. During the field season of 2023, fuel reduction work, in the form of cutting and hand piling, was completed at two highly fire sensitive sites. The result was a diminished fuel load within the site boundaries giving the resource a better chance of survival should a wildland fire spread through the area. The goal of the Fire Archeology Program is to continue using fuel reduction techniques to promote cultural resource protection during a time of changing landscapes and severe fire.

Keywords: *Fire; Archeology; Cultural resources; Traditional ecological knowledge*

Exploring White-Tailed Ptarmigan Habitat Selection In Rocky Mountain National Park

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While it is predicted that many wildlife species will shift their ranges upward in response to climate change, species in alpine ecosystems already exist at the highest elevations with no opportunity to move. The white-tailed ptarmigan (*Lagopus leucura*) is an alpine endemic grouse species found across Colorado facing an uncertain future in the state due to climate change, land use change, and increasing human recreation. To help guide management and predict future changes in white-tailed ptarmigan habitat, we first need an understanding of current habitat requirements across seasons. We used location data from radio-marked white-tailed ptarmigan collected at Rocky Mountain National Park (ROMO) from 2013–2016 and 2022–2023 in a resource selection framework with remotely sensed environmental covariates to model habitat relationships. We found white-tailed ptarmigan use habitats at high elevation that contain greater snow cover. Anthropogenic effects were overall weak, but white-tailed ptarmigan avoided areas with higher road density. Land cover and vegetation characteristics had relatively little influence on habitat selection, yet white-tailed ptarmigan selected increased shrub and bare ground cover. Overall results from these analyses indicate white-tailed ptarmigan habitat use in ROMO is largely driven by abiotic factors that are predicted to change under future climate scenarios, which will ultimately reduce usable habitat. Ongoing research aims to model quality white-tailed ptarmigan habitat within ROMO and across Colorado to help prioritize areas that can be protected to allow for their continued persistence.

Keywords: *Alpine; Resource selection; White-tailed ptarmigan; Wildlife*

Proactive Limber Pine Conservation Program – Going Strong After 15 Years

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In 2008, Rocky Mountain National Park entered a partnership with the USDA Forest Service (USFS) to develop a Limber Pine Conservation Program to address the mountain pine beetle (MPB) epidemic and the threat of white pine blister rust (WPBR; caused by the non-native pathogen *Cronartium ribicola*). The overarching program goals were to conserve the genetic diversity of limber pine and develop and implement proactive strategies to reduce the loss of this valuable tree species from montane, subalpine, and treeline ecosystems. The USFS helped provide the scientific foundation to meet these goals and led the development of the Limber Pine Conservation Strategy (2015; 2019). Seventeen study areas stratified by latitude and elevation were established in which target seedtrees were identified. More than 300 individual-tree and 50 bulked seed collections (> 212,000 seeds total) provide material for (1) the ex-situ genetic archive, (2) testing for genetic resistance to WPBR, and (3) restoration plantings. The seedtrees are protected yearly from MPB attacks with verbenone for in-situ conservation. Progeny from 133 seedtrees have been tested for WPBR resistance, revealing numerous trees with qualitative resistance. Bulked seed lots are being grown for post-fire restoration plantings. Three monitoring networks assess (1) forest health and mortality, (2) WPBR early detection and assessment, and (3) WPBR virulence. MPB causes the greatest mortality of limber pine, however, WPBR was discovered in the park in 2010. In 2017, there was a WPBR outbreak in the Beaver Ponds area and since then infected trees have been found in most study areas as the disease spreads. No change in WPBR virulence has yet been detected indicating that the identified WPBR resistance remains effective, for now. Expanding WPBR resistance screening to include other resistance mechanisms is essential for long-term management. This program is the outcome of dedicated park and USFS personnel and community volunteers.

Keywords: *Limber pine; White pine blister rust; Forest health; Genetic conservation*

Climate And Water Balance Effects On Rocky Mountain Wetland Hydrology; Challenges And Opportunities

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Wetlands are iconic habitats in the Rocky Mountains supporting critical biodiversity. The persistence of wetlands depends on a delicate and complex water cycle or "water balance" (WB) that drives hydrologic regimes. We analyze ground water (DTW) data from long-term monitoring conducted from 2007 to 2022 in five protected landscapes including RMNP. DTW data were generated for 49 sites classified into five wetland types. We develop WB for each site across our period of record. We model drainage (cumulative runoff from WB) against historical DTW time series, connecting the water cycle to site-level ground water dynamics. To forecast these relationships, we derive monthly future climate normals under three climate change scenarios and, using our historic WB relationships, generate a future WB and ground water hydrological regime for each site through 2100.

Models of historic ground water showed a strong relationship with drainage. Relationships were best in surface water influenced riparian wetlands but also good in ground water driven fens. DTW levels over our decade+ of historical data were generally stable to increasing (becoming wetter). However, especially under the more severe emissions scenarios, our models indicate that drainage is expected to markedly decrease causing many wetlands to become meaningfully drier. For example, some wetland types may dry by up to 33%, with the greatest change in RMNP where future temperature increases are expected to be less mediated by increasing precipitation. This suggests important wetlands, for example in the Kawuneeche Valley (KV), face an accelerating collapse in function. Most KV wetlands are already degraded from overuse by elk and moose, a lack of beaver enhanced hydrology, and a history of human manipulation (largely prior to the establishment of the park). Proactive management in the near term presents an opportunity to reduce further loss of these important ecosystems.

Keywords: *Wetlands; Ground water; Water balance; Climate change; Collapse*

Limber Pine Seed Viability And Seedling Survival Of Treeline And Subalpine Provenances: Trends Over A High-Elevation Stress Gradient

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Limber pine (*Pinus flexilis*) is a keystone species of conservation concern in Rocky Mountain National Park, important for its production of nutritionally dense seeds at high elevations and threatened by spreading white pine blister rust. Bioclimatic envelope models predict limber pine's distribution will shift to higher elevations with changing climate, but the pine's ability to do so depends on viable seed production nearby. Seed production in the alpine treeline ecotone (ATE) is adversely affected by low summer precipitation, short growing seasons, and pollen limitation, among other factors. However, limber pine in the ATE has been observed to produce well-developed seed cones. We estimated the rates of limber pine cone and seed production across a high-elevation stress gradient, moving from upper subalpine forest to above timberland and into the ATE, in both a non-mast and mast year. We determined seed viability through a combination of germination trials and seed dissections with application of tetrazolium dye. We found that viable seed production declines by an estimated 1.0 viable seed/cone every 100 m of distance, moving from subalpine forest above timberline and into the ATE, and by 5.7 viable seeds/cone per 100 m of elevation increase. During a mast year, limber pine produced a mean of 30.4 (26.0-35.3) viable seeds/cone in subalpine forest 400 m below timberline compared to 15.3 (9.6-15.9) viable seeds/cone from above timberline and into the ATE—a decrease of 50%. While seed viability data in the ATE is sparse, this estimated decline is comparable to rates of decline observed for whitebark pine at treeline. Seeds germinated in this study were planted and seedlings were raised for restoration planting in the Cameron Peak burn scar in Rocky Mountain National Park. We will present survival data for seedlings raised from seed provenances across the high-elevation gradient and from three treeline sites in RMNP.

Keywords: *Limber pine; Climate change; Seed viability; Treeline*

The Influence Of Wildfire On Genetic Diversity Of Trout In Rocky Mountain Headwater Streams

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Wildfire is a major form of ecological disturbance and an important driver of ecosystem dynamics in the western United States. In Rocky Mountain headwater streams, common short-term effects of wildfire include ash inputs and channel-reorganizing debris flows that can result in mortality and reduced abundance of trout. Patterns of genetic diversity may be influenced by such events due to population bottlenecks, but very little research has explored the genetic consequences of wildfire for aquatic species. To investigate the effects of wildfire on spatial and temporal patterns of genetic diversity in trout, we studied populations of brook trout (*Salvelinus fontinalis*) within and around the burn perimeters of the Cameron Peak and East Troublesome fires. In the summer of 2020, these fires burned over 400,000 acres combined, including 9% of Rocky Mountain National Park. Data on fish population responses revealed that trout abundance decreased at burned sites, suggesting the possibility of genetic bottlenecks. Using microsatellite genetic data collected at multi-year study sites from 2019-2023, we quantified pre- and post-fire genetic diversity at burned and unburned sites using effective population size (Ne), allelic richness (AR), and expected heterozygosity (HE). Further, we used genetic clustering algorithms to examine changes in population structure within a 60km continuous stream network in the Long Draw region before and after fire. With recent trends of larger and more frequent wildfires, understanding their effect on genetic diversity is needed for devising trout management strategies and predicting the resilience of species to environmental change.

Keywords: *Trout; Genetics; Fire*

Perceptions Of Human Waste Impacts In The Longs Peak Area Of Rocky Mountain National Park

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Increased visitation to Rocky Mountain National Park's Longs Peak area has resulted in more issues with human waste, particularly in the Park's fragile tundra where it is more difficult to dig a proper cat-hole. Forty-four group visitor interviews were collected in the Park's Longs Peak area from June to September 2023, to understand and improve human waste management practices. More than half of the sample indicated experiencing some type of litter (mostly micro-trash) while only five interviewed groups noted experiencing human waste while hiking in the park. Backpackers in the sample were consistently well-educated regarding Leave No Trace recommendations for cat-holes and use of wagbags. General day-hikers were relatively knowledgeable about recommended disposal practices, but they largely relied upon use of the privys (when they are open) instead of digging cat-holes or using wagbags. The vast majority of respondents indicated willingness to comply with wagbag/carry-out strategies if the Park were to implement these approaches. Respondents indicated more willingness to comply if the Park mandated a carry-out strategy, and provided wagbags for visitors to use. Regarding potential education strategies for further educating the visiting public about waste disposal, approaches that leveraged humor, aspects of health for humans and the environment, and informing visitors about the sacred nature of the mountains were perceived as most effective. These findings can inform visitor management and associated educational strategies in the Longs Peak area, as well as other popular locations in the Park.

Keywords: *Visitor management; Human waste management; Leave No Trace*

Impact Of Slash Pile Burn Scars On Plant Community Composition Across A 5-Year Chrono Sequence

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Slash pile burning is widely used to manage timber stands by reducing fire fuel loads. These piles are constructed of dead trees including logs, branches, twigs, and needle litter. While this management practice reduces fuel loads, there is potential for negative impacts to the vegetation recovery and seed bank. The objectives for this research were to determine the impacts on the vegetation, seed bank, and establishment of invasive plant species. In 2021, we sampled vegetation and soil from 40 slash piles at Rocky Mountain National Park that were burned from 2016-2020 (8 slash piles from each burn year). Total vegetation cover and seed bank density increased as the distance from the center of slash piles increased. There was a low quantity of invasive plant species overall. In slash piles where invasive species were present, we found a higher probability of finding invasive species inside the burned area compared to outside the burned area. Annual species cover was greater closer to the center of the burn scar, while perennial species cover increased as distance from the center increased. The implication for this study is to reduce the number of slash piles. If that is not feasible due to increased fuel loads, then we would recommend to managers to revegetate (i.e., seeding) burn scars can help increase vegetation cover.

Keywords: *Invasive species; Slash piles; Seed bank*

Poster Presentations

The Great Outdoors? Discrimination Theory And Black Park Use

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Numerous studies have shown that Black people do not visit National Parks at the same rate as their white counterparts. Leisure study scholars discuss four prominent theories for Black park disuse: marginality, ethnicity, assimilation, and discrimination. The marginality theory proposes marginalized people are lacking in resources that facilitate park use due to historical discrimination. The ethnicity theory suggests attending parks is not how Black people prefer to spend their leisure time while the assimilation theory argues that park-based activities were not originally part of Black culture, but eventually Black people will assimilate and adopt it as part of their culture. Much of the support for these theories is ahistorical and does not consider how history has affected Black people's relationships with the environment. To address this literature gap, this presentation engages in historical anthropology and political ecology to discuss the four prominent Black park disuse theories. Through these frameworks, this project argues that discrimination theory, the idea that discrimination is the primary factor in Black park disuse, is the primary reason for Black park disuse. Furthermore, this project asserts that the other theories are products of discrimination. This presentation will consist of a literature review and examine the history of Rocky Mountain National Park and the surrounding area as a case study. Furthermore, this project will address the questions "How has history shaped Black people's relationship with public leisure spaces?" and "Why has Black park use remained low?"

Keywords: *Park use; History; Race*

Recreation Ecology Meets Landscape Ecology: Understanding Visitor Use Disturbance On Habitat Connectivity And Potential Habitat Fragmentation

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Habitat fragmentation is often considered a key driver of biodiversity decline. Parks and protected areas (PPA), such as Rocky Mountain National Park, often represent critical strongholds of high-quality habitat for various wildlife species and function as key patches within the larger context of the landscape. In many of these areas, we have built and maintained infrastructure to support and encourage tourism and outdoor recreation. A limited number of recreation ecology studies have looked at the landscape-scale fragmentation resulting from the presence of visitor use infrastructure (e.g., informal trails and sites, roads). However, these studies have not examined habitat-specific fragmentation or habitat connectivity. Additionally, not every area within a PPA experiences the same levels of visitation and use. A busy day use trail would create a very different kind of human presence on the landscape compared to the infrequent use of backcountry trails. This collaborative study quantifies the distribution of visitor use on roads and trails and the impact of different levels of visitor use on potential habitat fragmentation and habitat connectivity in Rocky Mountain National Park. Landscape ecology approaches were applied to combine spatial data on visitor use levels, predicted at the park-wide scale, on roads and trails with ecological and habitat data. Results from this study can be used to inform future research studies or visitor use monitoring and planning. This sliding scale of fragmentation for various habitats can also provide park managers with areas deserving of focus while they balance the maintenance of critical habitats with increasing visitor use levels at PPA.

Keywords: *Visitor use management; Recreation ecology; Habitat fragmentation; Habitat connectivity*

Specimens, Artifacts and Archives into a Digital Landscape

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The Rocky Mountain National Park (RMNP) museum program is creating content for entry into the 21st century of information access. Rocky Mountain Conservancy (RMC) financial support and logistical support provide the means to the museum program to make collections more accessible. The Dept of the Interior is launching a cloud-based museum collections platform which will be accessible to staff in 2025 and to the public in 2026. RMC is funding digitization projects for historic maps and plans, historic photograph albums, archival records, and oral history interviews. They have funded the project of photographing all the natural history specimens in RMNP museum collections.

In addition, RMC support provides matching funds with NPS funds for a) storage improvements in the museum storage facility; b) conservation work on artwork, furnishings, Holzwarth Historic site objects and taxidermied head mounts, c) the digitization of historic photographs, databasing and Cold Storage for long-term preservation (think 100-500 years); and, d) museum guidance documents including an archives survey and HHS exhibit / furnishing plan.
The digitization efforts were paid in part by RMC and RMNP cultural cyclic maintenance project funds, and these projects were staffed by members of the RMNP museum program.

Credit goes to all partners for positively and dynamically addressing challenges and joining in collaboration for a changing learning landscape.

Keywords: *Museum; Digitization; Access; Discovery*

Plains To The Park: Community Science In The Rocky Mountains

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Westview Middle School Students

Plains to the Park is a STEM program hosted by Westview Middle School (St. Vrain Valley). Since 2014, students have been working to build understanding of ecological and environmental issues facing Rocky Mountain National Park. The Fall River corridor (Horseshoe Park) is where students collect trail camera data, in order to answer the questions "who lives in this place?" and "how is that changing over time?"

Collaboration has been at the heart of this program. In addition to the work that we do on our trips, Plains to the Park has presented at the past 3 RMNP research conferences and attended the RMNP 100th anniversary celebration. We also hosted a group of South Korean STEM students for a presentation at our school, and then a wintry trip to Rocky to check our cameras. We created an exhibit for the University of Colorado's Museum of Natural Science, which ran for roughly one year. Eight years ago, we began our partnership with the City of Longmont's Button Rock Preserve (foothills). We check and maintain cameras there, too. That relationship continues to thrive today. Plains to the Park also inspired a similar program at another St. Vrain Valley Middle school. Longs Peak Wildlife Rangers program partners with Boulder County Open Space.

Over the past ten years, hundreds of Westview students have chosen to participate in a Plains to the Park trip on a non-school day. They have learned about community science by contributing to the process. They've learned about science literacy by communicating their learning. They've learned about the assets and wisdom behind national parks, and all public lands by participating in Community science. They've learned the concept of stewardship by sharing their stories with their families, friends and fellow students. Plains to the Park appreciates the opportunity to share its story with you.

Keywords: *STEM; Community science; Middle school; Outdoor learning*

Clonal Plants In Alpine And Ecotone Communities

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Jordan Conley

Two-thirds of plant species may possess some form of clonal growth, emphasizing the importance of studying traits related to clonality in the context of environments and global change. Despite known benefits, traits related to clonality may have tradeoffs. For example, plants may position rhizomes deep in the soil, insulating them from frost, but this may result in delayed emergence and reduced growth due to the energetic cost of a deep rhizome. There is a similar energetic cost to maintaining spacers used in lateral spread. This suggests such energy investment may be less effective in some environments, as illustrated by lower cover of species with a high rate of vegetative spread in alpine environments. In contrast, bud bank size has been observed to increase with elevation. Additionally, bud bank density increased with decreasing temperatures and increasing precipitation, such as what we see along the elevational gradient of Colorado. Understanding the benefits and tradeoffs of various clonal traits will help to predict future climate change responses and general disturbances, but information is lacking, especially on the role of clonality in community dynamics. We compared vegetation in alpine, ecotone (krummholz), and subalpine forests, an elevational gradient in temperature and moisture. We expected clonal species to increase in percent cover as the elevation increases, and that lateral spread would decrease and bud bank size increase as elevation increases. Finally, we hypothesized that plants at a higher elevation will use a more conservative strategy concerning traits and performance. We found clonal traits to dominate the cover of alpine and krummholz elevation communities, but more so in alpine environments. Preliminary results suggest bud bank does appear to increase with elevation, but lateral spread was not significantly different. High elevation species use a more conservative strategy, and these traits can predict community response to climate change.

Keywords: *Vegetation composition; Alpine; ecotone; Clonal*

Direct And Indirect Effects Of Wildfires On Rocky Mountain Lake Ecosystems

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Decades of fire suppression and shifting climate regimes have increased wildfire occurrence frequency and size across the globe. The effects of wildfires on mountain lake ecosystems has been previously researched, but studies comparatively assessing the direct and indirect impacts of fires in the Rocky Mountain region have yet to be conducted. We propose an analysis of two mountain lake ecosystems, The Loch and Fern Lake, Rocky Mountain National Park, to understand the direct effects of the East Troublesome fire on Fern Lake and to understand the indirect effects of fires over a 40-year period on The Loch Vale. Previous studies have found erosion-driven increases in sedimentation and turbidity, as well as increases in nutrients and changes to dissolved oxygen and temperature in burned watersheds. However, far more Rocky Mountain lakes are influenced by the indirect effects of regional or continental-scale fires that alter air quality and solar radiation. Using long-term meteorological data from the Loch Vale weather station and historical data pertaining to large regional fires, fire effects on the lakes will be evaluated in the context of ash deposition, reduced solar radiation, and novel temperatures. We will analyze observational data to find responses in lake biogeochemistry, temperature, oxygen, and algal primary productivity. We expect to see short-term increases in total nitrogen, short-term increases in net primary productivity for The Loch and Fern Lake, short-term decreases in temperature for The Loch during fire periods, and short-term decreases in dissolved oxygen for The Loch and Fern Lake through analyses of trends over seasons and years. This analysis may provide ecosystem managers the tools to understand the small-scale and broad-scale effects of fire on lake ecosystems across the Rocky Mountain region.

Keywords: *Fire; Mountain lakes; Biogeochemistry; Rocky Mountain region*

Metal And Nitrogen Contamination In Poudre Lake And The Potential Impacts On Microbial Nitrogen Cycling Activities

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Metal and nitrogen deposition in Rocky Mountain National Park has increased since the mid-20th century. Most studies attribute increases in atmospheric nitrogen deposition to air pollution from the Urban Front Range Corridor and eastern Colorado plains. However, Poudre Lake is less than 10 meters from Trail Ridge Road, and therefore likely receives substantial nitrogen and metal loadings from road run-off. This study uses sediment core analysis to reconstruct the past 300 years of metal contamination and nitrogen deposition in Poudre Lake. Potential ecological impacts of sediment contamination are explored by characterizing potential nitrogen cycling functions of sediment microbial communities. Sediment microbial communities play a key role in nitrogen removal, yet little is known about how combinations of metal and nitrogen contaminants influence nitrogen cycling activities.

Copper, zinc, lead, cadmium, and total nitrogen fluxes increase dramatically after the construction of Trail Ridge Road and correlate positively with RMNP visitor count. Increases in nitrogen cycling genes *nirS* and *nosZ* start around 1930 CE and then drop back down in the 1970s. This pattern in *nirS* and *nosZ* may reflect a past response of microbial communities in the water column or surface sediment to new inputs of metals and nitrogen following road construction. Results indicate that roadside lakes in RMNP are impacted by metal and nitrogen contamination from vehicle exhaust and non-exhaust emissions. As visitor traffic continues to increase, infrastructure modifications may be needed to mitigate metal and nitrogen loadings to roadside lakes in the park.

Keywords: *Metals; Nitrogen; Lakes; Microbe*

Activating Volunteers For Ecological Monitoring And Building Visitor Engagement In Conservation In Rocky Mountain National Park

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The American pika (Ochotona princeps) faces an uncertain future due to the complex ecological impacts of climate change. Due to their sensitivity to temperature changes and specificity of habitat needs, pika are predicted to experience declining distribution and local extirpations in parts of their geographic range. The Colorado Pika Project (CPP) aims to detect issues early and do predictive work to identify management actions that could reduce pika losses in the Southern Rocky Mountains.

Since 2010, the CPP has trained 625 community science volunteers to collect data on pika and their habitat characteristics to understand the factors influencing pika persistence in Colorado. In 2018, the CPP expanded into Rocky Mountain National Park to collect data at 79 sites. Through active engagement of volunteers in ecological monitoring, we are able to collect a significantly larger amount of data than would otherwise be possible. In 2023, CPP staff and volunteers conducted 270 pika surveys, 110 of which were in RMNP. Early data from 2017-2020 suggested that pika habitat occupancy may decline with temperature and increase with rock crevice depth. Improved models of habitat occupancy are being developed with larger sample sizes from 2021-2023.

While our core volunteer program requires intensive training and activates mainly Coloradans, our Pika Patrol App provides an avenue for anyone to report pika observations and habitat data without formal training. The app is a valuable tool to engage park visitors from anywhere in the world to contribute meaningful data to pika research. Participation in science increases the public's understanding of the challenges and complexity of addressing climate change, species conservation, and protected area management. The CPP serves as a model for how to activate communities to collect valuable data to inform management decisions and serve as ambassadors for conservation.

Keywords: *Pika; Community science; Volunteers; Visitor engagement*

Tracking Plant Phenology In The Alpine Using Community Science

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In Rocky Mountain National Park's alpine ecosystem, the growing season is short, and impacts of climate change are a concern. To track the possible effects of climate change on alpine plants, we are implementing a community science program to track alpine plant phenology. Phenology of plants can be narrowed down to four reproductive stages: leaf-burst, budding, flower, and senescence. We chose the Bettie Willard research plot at Rock Cut for the location of this research due to its historical scientific research significance, as well as its ease of access for visitors. A two-pronged approach will be applied to tracking alpine plant phenology: one with trained VIPs (volunteers-in-parks) and another oriented toward visitors. The trained VIPs will track every flowering plant in the research plot, while park visitors will look for selected plants, based on ecological significance, charismatic species, or as indicators of seasonal change. In the first year of the project, we have accomplished setting up a program, running it with trial groups, and collecting preliminary data. With this data, we hope to inform future park management decisions. This project will also engage visitors with park resources in a new way to help foster park stewardship and science literacy. Moreover, this will connect climate change to the alpine tundra experience in a unique way for visitors, park staff, and VIPs alike.

Keywords: *Phenology; Alpine plants; Climate change; Community science*

Restoration Prioritization Of Upper Colorado Tributaries In The Kawuneeche Valley: Preliminary Results

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The collapse of tall willow habitat and beaver populations along Upper Colorado River tributaries in Rocky Mountain National Park, CO has led to loss of ponded water on floodplains, channel morphologic changes, and sediment loading downstream. The National Park Service (NPS) and a diverse stakeholder group is pursuing channel restoration on Upper Baker, Lower Baker and Onahu Creeks to increase channel-floodplain connectivity and improve tall willow habitat and downstream water quality. In this study, we will develop and apply a restoration prioritization scheme based on the historical and contemporary fluvial geomorphic context of the three study sites. Utilizing a combination of historical records, field data, and flow inundation modeling, we will investigate the processes driving channel incision, bank failure, and levels of floodplain connectivity. Preliminary data were collected at Lower Baker Creek in 2023 and indicate that Lower Baker Creek has an average channel slope of 0.3% and a bed substrate of medium to coarse gravel (D_{50} of 5.3 mm – 24.0 mm). Channel banks are up to 80 cm high and consist primarily of silt and sand, with a discontinuous underlying gravel and cobble layer that forms undercut banks where eroded. Relic beaver dams were noted throughout the reach. Floodplain sediment depths are up to 200 cm, consisting primarily of silt- to cobble-sized sediment. These initial findings indicate that Lower Baker Creek historically experienced frequent overbank flooding, migrated across the floodplain, and was heavily influenced by beaver activity. Similar data will be collected at the Upper Baker and Onahu study reaches in 2024 to provide recommendations for prioritizing restoration to the NPS. Developing effective, long-term restoration strategies requires a better understanding of historical and current geomorphic processes in fluvial systems to achieve the greatest river ecosystem benefit.

Keywords: *Channel restoration; Floodplain connectivity; Geomorphic context*

Detecting Invasive Grasses Across Elevational Gradients Using Predictive Phenology Models And Remote Sensing

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Invasive annual grasses reduce ecosystem productivity, negatively impact biodiversity, and are becoming increasingly problematic in higher elevation ecosystems following disturbances. The timing of growth and senescence of invasive grasses varies greatly across elevational gradients and from year to year, making management planning difficult and reducing the ability to map them using aerial or satellite imagery across topographically diverse terrain. To address this issue, we created landscape-scale predictions of the phenology of one invasive grass species, cheatgrass, parameterized using volunteer science observations, long-term monitoring experiments, and time-lapse camera imagery. We fit growing-degree day models to these data to predict the timing of peak greenness and senescence of cheatgrass across latitudinal and altitudinal gradients and over multiple years. We used these predictive models to select moderate-resolution satellite imagery to map potential cheatgrass populations across mountainous landscapes in southern Wyoming and northern Colorado. We then compared our maps to on-the-ground cheatgrass cover measurements collected in 2021 following the Mullen and Cameron Peaks fires to assess the accuracy of these new methods. Cheatgrass detection maps derived from differencing normalized-difference vegetation index (NDVI) values between Sentinal-2 images selected during predicted peak greenness and senescence dates as informed by the predictive model correlated with on-the-ground measurements of cheatgrass cover. Using mechanistic, predictive phenological models to select and difference remotely-sensed imagery is a promising technique to detect and map invasive species with distinctive phenology, especially across environmentally diverse landscapes. However, the accuracy of detection maps depends greatly on the availability of cloud-free imagery during phenologically-relevant dates in a given year.

Keywords: *Cheatgrass; Invasive species; Climate change; Remote sensing*

Soil Carbon Stability In Alpine Tundra

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Tundra systems have historically been sinks for soil carbon as the diminished temperature suppressed microbial activity. With warming temperatures, it is thought that these systems could transition from sinks to sources of carbon. However, other soil parameters may influence soil respiration and the overall stability of carbon in this system. In June of 2015, four study sites were established in alpine tundra in Rocky Mountain National Park. Soil respiration, soil temperature, and soil moisture were measured twice monthly throughout the snow-free periods of 2015-2021 using a LI-COR LI-8100A automated CO2 flux system and digital probes. Soil samples were collected monthly using a 1-inch diameter corer to a depth of 15 cm. In the lab, soil concentrations of nitrogen and phosphorus were measured using a colorimetric approach. Soil carbon was measured using a total carbon analyzer. Soil pH was measured using a Hach pH probe. Generalized least squares regression was used to investigate the relationship of soil respiration to temperature, moisture, and the other measured variables. Across all plots, soil respiration was significantly related to soil temperature, soil moisture, and possibly the interaction of the two ($p < 0.05$). The relationship was quadratic; respiration was suppressed at high and low soil temperatures and soil moistures. Soil respiration was unrelated to all other variables ($p > 0.05$). These findings suggest that, in the alpine tundra, an increase in temperature alone may not result in a loss of soil carbon. Current climate models predict an increase in temperature over the next century, but the future of soil moisture is less clear since it depends not only on the magnitude of precipitation, but the type of precipitation and the timing of snowmelt.

Keywords: *Climate change; Soil; Tundra; Carbon*

Development Of A Hyperspectral Endmember Library For Limber Pine And Other Treeline Plant Species In Rocky Mountain National Park: Convolutional Neural Network Classification Of Species Reflectance Profiles For Remote Sensing Applications

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Limber pine (*Pinus flexilis)* is an ecologically important conifer in the Central Rocky Mountains that ranges from lower montane forests to upper treeline and faces the combined threats of mountain pine beetle (*Dendroctonus ponderosae*) outbreaks, infection and mortality from white pine blister rust (*Cronartium ribicola*), and a changing fire regime that could further fragment its metapopulation. As climate warms, limber pine is projected to move upward in elevation into present-day tundra communities. However, the current limber pine distribution in the alpine treeline ecotone (ATE)—rangewide and in Rocky Mountain National Park (RMNP)—has not been mapped. We developed field spectroradiometer collection methods for eight plant species commonly found in the ATE in RMNP, including limber pine, and collected reflectivity profiles comprising a spectral endmember library for these species for future remote sensing classifications. We trained convolutional neural networks to determine whether these species can be discriminated based on hyperspectral data and to identify wavelengths that are important for separating these ATE species. Fairly high classification accuracies were achieved for all three CNN models—68.9% for the eight-class model, 85.3% for the four-class model (conifers vs. other), and 93.4% for the two-class model (limber pine vs. everything else). We will next determine whether these data can still be used to discriminate species when averaged to equivalent eight-band multispectral WorldView-3 data. This information will enable us to determine the spatial and spectral resolution data requirements for discriminating these ATE species in RMNP using remote sensing technologies.

Keywords: *Limber pine; Remote sensing; Machine learning*

Convolutional Neural Network Classification Of Six Alpine Treeline Ecotone Plant Species Using High-Resolutionworldview-3 Satellite Imagery: Applications For Limber Pine Conservation

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Limber pine (*Pinus flexilis*), a keystone species of conservation concern in Rocky Mountain National Park (RMNP), is anticipated to migrate to higher elevations above the present timberline with changing climate. However, its current distribution in the alpine treeline ecotone (ATE) has not been mapped. Treeline locations are often difficult or dangerous to access, making them ideal targets for applications of remote sensing technologies. While drones provide high spatial resolution, few drones are built to withstand high windspeeds that can occur at these high-elevation locations. Lidar and hyperspectral data can reliably be used to discriminate tree species, but these data are expensive to collect, involving aircraft overflights. We present the first application of satellite imagery to ATE plant species classification, using high spatial resolution WorldView-3 panchromatic and multispectral imagery. We trained three convolutional neural network models aimed to separate limber pine from other dominant ATE shrub and tree species: a six-class model separating all species, a four-class model separating the three conifers from one another and from a pooled class of the three deciduous species, and a two-class model separating limber pine from the five other ATE species. The three models had low to moderate overall accuracies of 46.23%, 51.55%, and 85.33%, respectively, and the CNNs relied heavily on the 31 cm panchromatic imagery. However, this experiment elucidated the data requirements for classification of krummholz trees in the ATE using satellite imagery and will be informative for future investigations. We aim to improve model accuracies by including WV-3 imagery obtained during fall senescence and 8-band shortwave infrared imagery. Our work here lays the foundation for discriminating ATE plant species at larger geographic scales, in RMNP and throughout limber pine's geographic range.

Keywords: *Limber pine; Remote sensing; Machine learning*

Interpretive Perspectives: Concentrated And Effective Efforts

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With a recently completed strategic planning process, the Cache la Poudre River National Heritage Area (Cache NHA) will refocus current systems to refine their purpose, quality, and impact to further overall public engagement. With a goal to tell more inclusive stories, a new theme for interpretation has been identified as well as three key recommendations to concentrate the efforts of staff and drive more effective efforts across the heritage area. The new interpretive theme focuses on the interconnectedness of varied cultures and ecology and includes seven new sub-themes to explore. Over the coming years, Cache NHA will be positioning itself to become a champion for interpretation, resources, and coordination while creating space for like-minded professionals to gather. Lastly, the strategic interpretative plan has outlined a clear path to overhaul virtual offerings and focus on real-world visitation strategies. This session will explore the under told sub-themes in the heritage area and review the recommendations provided in the strategic interpretive plan.

Keywords: *Interpretation; Inclusive stories; Strategic planning*

Examining Boulderers' Perceptions Of Leave No Trace In RMNP From 2015 And 2023

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Bouldering, or rope-less climbing continues to be a popular activity in Rocky Mountain National Park. The Park features some of the most iconic bouldering problems in the West, highlighted in guidebooks specific to bouldering in the Park and frequent discussions via web apps and social media by the climbing community. Given the popularity of this sport in the Park, and potential social and ecological impacts associated with this unique activity, we conducted a study in 2015 to understand boulderers' perceptions of Leave No Trace. Results informed specific educational strategies and outreach by Leave No Trace, the Access Fund, and the park. In 2023, we revisited this study by surveying boulderers with the same questions, to see if attitudes and self-reported behaviors had shifted over the past eight-years. In an effort to understand the current state of boulderers' behaviors and attitudes toward Leave No Trace practices, a total of n=213 responding boulderers, answered an updated survey at three sites in Rocky Mountain National Park, as well as through QR codes in nearby climbing gyms. Results demonstrated a significant change in boulderer's attitudes and self-reported behaviors since the original study in 2015. Results suggest that Leave No Trace education (i.e., bouldering specific Leave No Trace "hangtag"; climbing stewards program launched by the Park; educational outreach at nearby climbing gyms) contributed to significant positive changes among the park's bouldering community. While challenges remain, such as storing and stashing crash pads, this longitudinal study points to the power of education in aiding with visitor management and resource protection.

Keywords: *Visitor management; Leave No Trace; Bouldering*

Genetic Diversity of Montane Grasshoppers under Climate Change

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Organisms in montane environments are at greater risk of decline as climate change exacerbates environmental stressors that impact survival, reproduction, and dispersal. Insects are especially at risk due to their inability to regulate their body temperatures. Montane short-winged grasshoppers are important indicators of ecosystem stress related to climate change in particular because of their small dispersal ranges and short growing periods. Short-range dispersal limits their ability to migrate to other mountains to avoid extreme environmental conditions and limits the flow of genes between populations. This hampers their ability to adapt to environmental conditions in the case of climactic events. Short growing periods also limit the ability of grasshoppers to shift timing of adulthood to avoid harsh conditions which could put them at risk of extinction.

This project focuses on the genetic variation between populations of one of these short-winged montane grasshopper species, *Melanoplus boulderensis*. I have sampled along elevational transects throughout Colorado and New Mexico to analyze how climate change may affect genetic variation. By examining these species across wide elevational ranges, I can evaluate how climate change may affect genetic diversity at lower and high elevations and identify those populations most at risk of extinction. This information can be used to develop knowledge on the impact of climate change (or other environmental changes, such as alterations to fire regime) on dispersal-limited montane insects and better inform conservation decisions in mountain regions that have high risks of biodiversity loss as well as better informing the stability of current populations.

Keywords: *Climate change; Gene flow; Genetic diversity; Elevational gradient*

NEON In Rocky Mountain National Park: Expanding The Scope Of Ecological Science Through Long-Term, Open Access Ecological Data

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The National Ecological Observatory Network (NEON) is a continental-scale program that collects long-term, open access, ecological data to better understand how ecosystems are changing across the United States. NEON provides data from 47 terrestrial and 34 aquatic field sites, including a terrestrial field site within Rocky Mountain National Park (RMNP). NEON data cover a range of subject areas within ecology, including organismal observations, biogeochemistry, aerial lidar, hyperspectral imagery, and micrometeorology. All samples and data collected by NEON are publicly available and can be accessed digitally through the NEON website. By providing free and open standardized data, along with data analysis tools, tutorials, and educational resources - NEON is engaged in the global effort to expand the scope of science and make scientific data access easier for all. NEON's field site within Rocky Mountain National Park is essential to the continuation of the largest ecological data collection and monitoring program in the United States. Scientists from a variety of disciplines have conducted research using data and samples collected from the NEON site within RMNP. Since 2019, 29 papers using NEON data from the field site have been published. Many of these studies have used NEON data to investigate questions that contribute to our understanding of climate change and how the results can be applied to manage and mitigate the effects of increasing natural disturbances. This poster presentation will introduce NEON's terrestrial field site in Rocky Mountain National Park, showcase NEON data collected from this site such as remote sensing data, plant population and biomass data. It will also highlight the Observatory's Assignable Assets program, which makes components of NEON's infrastructure available to outside researchers and community members to support their research.

Keywords: *Ecology; Climate change; Open access data*

Moose Herbivory On Subalpine Fir In Rocky Mountain National Park

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Moose (*Alces alces shirasi*) populations in Rocky Mountain National Park (RMNP) have been increasing since the 1980s. Presently moose have been observed in drainages throughout RMNP and anecdotal reports of intense winter browsing of subalpine fir (*Abies lasiocarpa*) saplings prompted a pilot survey to determine the extent and severity of fir browsing. We collected data from 20 subalpine mixed conifer sites across RMNP during summer 2020, including data on structure and browsing of conifer trees, saplings, and seedlings, stand characteristics, and environmental variables. Overall, we found little indication of heavy and/or prolonged fir browsing at most sites. Roughly half of sampled fir saplings showed no signs of browsing, and only 11% had signs of recurrent browsing or heavy, prolonged browsing. Fir saplings showing signs of browsing severe enough to result in structural changes were confined to a few sites, primarily on the west side or near the northern boundary of RMNP. Mean current browsing on fir saplings was 12.3% ± 8.2%. Few significant correlations were found between higher proportion of browsed fir saplings and most stand characteristics. Greater moose dung density was observed at sites with greater proportion of fir saplings showing browse-induced changes in plant architecture ($r = 0.54$, $p = 0.05$), and these sites were also further from roads ($r = 0.51$, $p = 0.05$). Based on this limited research, we concluded that moose browsing of subalpine fir in RMNP was not currently at levels that would limit survival and sustainability of fir in subalpine mixed conifer stands. However, the effects of climate-change-driven drought, increasing temperatures, pest and disease outbreaks, and wildfires will likely play a role in how moose herbivory affects fir growth in the future and RMNP managers should consider limited monitoring of areas where effects of heavy and prolonged fir browsing were observed.

Keywords: *Moose; Subalpine fir; Browsing*