High Altitude Revegetation Committee –
Society for Ecological Restoration-Rocky Mountains Chapter
2019 Joint Conference

HAR – SER-RM 2019 Conference Program

Colorado State University
March 12 – 14

HIGH ALTITUDE REVEGETATION

SER ROCKY MOUNTAINS SOCIETY FOR ECOLOGICAL RESTORATION

High Altitude Revegetation Committee –
Society for Ecological Restoration-Rocky Mountains Chapter
2019 Joint Conference

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All events in Lory Student Center (LSC) Ballroom AB unless otherwise noted

Tuesday	March 12	
8:00 – 9:50 AM	Pre-Conference Workshop: Emerging approaches to overcoming cheatgrass on restoration projects	Gray Rock Rm. (LSC 290)
7:30 AM	Registration / Coffee	Outside Ballroom AB
10:00 – 10:15	Opening Remarks Pete Stahl and Mark Paschke	Ballroom AB
10:15 – 11:45	**Keynote Session 1** Moderated by Kristina Hufford	

10:15 Keynote 1: Leaping into the decade of restoration
Kingsley Dixon

As we move into the UN decade of restoration the demands grow for seed-based solutions that provide timely, effective and scalable opportunities. Technology developments, though developed in the US to a large degree yet poorly in the remainder of the world, represent one of the key impediments to delivering 'on-demand' restoration. Estimates of seed wastage in direct seeding programs from major restoration centres such as Australia and China, indicate that we still retrieve seed-to-plant conversions of just 10% or less. For biodiverse restoration this figure can be substantially less due to seed dormancy, low viability and inability to create the appropriate establishment niche following seeding. Developing an effective restoration toolkit that is built on sound science with a clear focus on practitioner application remains elusive for many restoration programs. I will outline global success stories in developing effective seed-based restoration and, importantly, how the soon to be published International Standards for Native Seeds in Restoration represents a key milestone for ensuring good seed delivers great restoration.

10:45 Seedbank-vegetation relationships in restored grasslands: applications for restoration planning, implementation, and evaluation
Andrew Rayburn

Seedbanks represent the pool of seeds of different species that could potentially recruit into the above-ground community. Seedbanks also serve as reservoirs of biodiversity and help maintain desirable native species. Analysis of seedbanks and seedbank-vegetation relationships has direct applications for habitat restoration. Western U.S. grasslands are increasingly restored to improve habitat and enhance ecosystem services. Studies of seedbanks and seedbank-vegetation relationships in restored grasslands are few, and extent to which planted species add seeds to seedbanks is rarely assessed although there are often significant challenges in retaining native species planting. We examined seedbank composition and seedbank-vegetation similarity within and between restored and unrestored California grasslands. We found a high degree of variation in both, suggesting patchy species distributions. We also found that few native grasses persisted in both seedbanks and vegetation in the years after planting, likely due to competition with exotic species and a lack of management. We also found no native grasses in seedbanks within unrestored fields, strongly suggesting that passive restoration will be ineffective. Through our approach, we demonstrate the utility of seedbank analysis for optimizing restoration implementation, monitoring restoration trajectories, and guiding adaptive management. We will emphasize how these results apply to ongoing efforts to restore Colorado grasslands.

11:05 Investigating restoration seeding outcomes: examples from the Wyoming Powder River Basin
Sara Burns

One of the many challenges in ecological restoration is the successful establishment of a diverse plant community. This approach commonly requires seeding of native plant species and represents a key regulatory practice in restoration of western ecosystems. Considerable information is available for decision-making in seeding, including the choice of seed mix and seeding techniques. However, seeding success is often not quantified. We investigated restoration seeding outcomes in the Powder River Basin over two years to survey vegetation at 15 reclaimed coalbed methane (CBM) wells compared with 15 nearby, undisturbed vegetation sites. Our objective was to characterize the species composition between reclaimed CBM well pads and original reclamation seed mixes, as well as species composition at nearby, undisturbed sites. We aimed to describe not only seeding success, but also the variation in plant species diversity and invasive weed density relative to undisturbed rangeland. We will discuss our findings in light of the overall success of the seed mix, native and non-native species diversity, and similarity indices comparing reclaimed and natural rangeland vegetation. Studies of restoration seeding suggest that success is often very low and declines over time. Given ecological and economic consequences of seeding failure, restoration practitioners need quantitative data for seeding outcomes to make critical decisions in reclamation of natural resource extraction sites.

11:25 A decade of seedling emergence evaluation and revegetation results in Northwestern Colorado

Rachael Ridenour

Evaluation of first-year seedling emergence following the seeding of a restoration project can be an indicator of the success of the seeding effort. Successful seedling emergence is often correlated with favorable precipitation for plant growth in the immediate months preceding emergence. This study compared seedling emergent density with eventual desirable plant cover at the Colowyo Coal Mine in northwestern Colorado. The pre-mining area was comprised of two community types, Sagebrush and Mountain Shrub, with precipitation ranging from 12-25 inches/year based on elevation. This study encompassed annual revegetation efforts initiated between 2004-2013. As a result, this study contains landforms which were constructed and seeded under a variety of climatic conditions. The landforms evaluated also exhibited various topographic conditions, including all aspects, elevations ranging from 6500-8000 feet, and slopes ranging from 0-25%. Revegetation treatments such as topsoil placement depth and seed mix were consistent from 2004-2007 and were updated in 2008. This study compared seedling emergent density with Year 7 perennial plant cover and considers the effects of climactic conditions on revegetation results. Eventual revegetation goals at the Colowyo Mine pertain to achieving bond release criteria for plant cover and production, as defined by the Regulations of the Colorado Mined Land Reclamation Board for Coal Mining Rule 3: Performance Bond Requirements.

11:45 – 1:15	Lunch	Ballroom CD
12:30 – 1:10	SER-RM Member meeting	LSC Room 376-378

1:15 – 2:35 Technical Session 1: Wetlands

Moderated by Tim Hoelzle

1:15 How should we be evaluating wetland restoration?

Jeremy Sueltenfuss

Making ecosystem restoration more effective and efficient has been a primary goal of restoration ecology. Because ecosystem restoration seeks to improve severely degraded lands, small improvements in ecosystem health are often promoted as success. However, when the restoration goal is to create a specific wetland type, as is often the case in wetland mitigation, the resulting wetland may be different than what was proposed. Performance standards are a tool used to evaluate wetland mitigation projects, yet the most appropriate performance standards to implement are unclear. Most projects use performance standards related to vegetation, and few include specific hydrologic performance standards. This presentation will highlight the utility of performance standards based on reference site hydrology, and the potential difficulty of using vegetation as the only performance standard. As can be seen in the presented case studies, a project has a greater chance of getting the desired vegetation when the hydrologic regime is restored. However, getting the right vegetation does not mean you have restored the correct hydrology nor created the proposed wetland type.

1:35 Restoring the vegetation structure and carbon storing function of a degraded wet meadow

John Hribljan

Tuolumne Meadow is one of the largest meadows in the Sierra Nevada Mountains. The meadow was heavily impacted by historic land uses including intensive sheep grazing from the mid to late 19th century. The natural rhizomatous and tufted wetland plant species that likely dominated the meadow pre-1850 has been largely replaced by upland plant species that no longer support the formation of organic rich wet meadow soils with a high water holding capacity. Our work involves testing if reestablishing a sedge dominated community can restore the carbon accumulating function of the meadow. We have planted over 38,000 *Carex scopulorium* seedlings and are measuring vegetation growth and ecosystem carbon exchange along a soil moisture gradient to understand the factors limiting the planting success and the effect of these plantings on soil carbon stocks. Our preliminary data show that two years post planting seedlings had more than twice the belowground biomass per unit area of other herbaceous species sampled. Despite seedling growth the meadow is currently a net source of carbon dioxide to the atmosphere. However, a significant relationship between carbon storage and percent vascular plant cover indicates that increasing vegetation cover could restore the meadow to a carbon sink. We propose that the short, cold growing season for this meadow combined with increasing drier climatic conditions are the main restoration challenges to reversing the system's current state as a carbon source.

1:55 Approaches for creating sustainable biomass production in a reclaimed fen in the Alberta Oil Sands region

Lewis Messner

The majority of wetlands impacted by oil sands mining in northern Alberta, Canada are peat accumulating wetlands, bogs and fens. The government of Alberta has legislated that disturbed areas be reclaimed to "equivalent land capacity." However, no guidelines exist for reclaiming peatlands in post-mined landscapes. I analyzed annual biomass production in response to seven planting methods, two seedling densities, and four cover treatments on a 2.9 ha fen constructed in 2013. *Carex aquatilis* and *Juncus balticus* were introduced to the fen as seedlings and seeds. By the fifth year, mean annual above-ground biomass (AGB) was comparable to natural fens while average below-ground biomass fell below natural peatlands. *Carex aquatilis* produced the largest proportion of AGB on the fen (54.45% ± 3.751; n = 59) and its proportion of the total increased from 2015 through 2017 in most treatments. *Juncus balticus* AGB decreased by 53.47% (se = 10.62) from the third to the fifth year and was highest where planted as seedlings (341.7 ± 25.25 g/m2; n = 68). The effects of cover treatments on AGB were evident in year three but not by the fifth year. *Carex aquatilis* and *J. balticus* AGB were weakly correlated to water table depth, and total below-ground biomass was the only response significantly affected by EC (R = 0.11, P = 0.038). Developing and testing methods for vegetating peatlands in post-mined landscapes is critical for reclaiming carbon-accumulating ecosystems in the oil sands region.

2:15 White River National Forest site-specific abandoned mine land restoration.
Randy Mandel

Since 2012 Randy Mandel has partnered with key White River National Forest (WRNF) personnel to provide site-specific restoration services. This talk will focus in on the implemented site-specific restoration and the accomplishments and challenges faced along the way. Much of the work has focused on AML program support through the collection, increase, and installation of ecotypic vegetation for Butterfly Burrell Mine, Hope Mine, and Emily Load/Lincoln Creek Restoration Sites. Ecotypic revegetation has been carried out in support of USFS AML reclamation efforts to reduce ecological risk, facilitate site stabilization, improve water quality, and protect watersheds. The desired outcome of this work includes returning the essential ecological functions and services of each site. Ecotypic species prioritization has been based on the predominant native grasses, forbs, and woody species that typify each site, and has consisted of seed collection, stratification, germination, cultivation, and planting of these prioritized materials. Seed collection has been carried out through partnership with WRNF, whereas plant propagation and increase has been accomplished through a combination of ecological consultants paired with plant production by Colorado Correctional Industry (CCI) and nursery personnel. Plant installation has been accomplished by CCI's State Wildland Inmate Fire Team (SWIFT) with oversight provided by WRNF and Mr. Mandel.

2:35 – 3:00 Break Ballroom CD

3:00-4:20 Organized Session 1: Forest restoration in Colorado Front Range ponderosa pine forests.

Moderated by Mark Paschke

3:00 Principles for the restoration of ponderosa pine and dry mixed conifer forests.
Mike Battaglia

As land managers increase the pace and scale of restoration in dry frequent fire forests, there is a need for science-based information to help inform these activities. In this presentation, we discuss a science-based framework for managers to develop place-based approaches to forest restoration of Front Range ponderosa and dry mixed conifer forests. We present ecological information describing how Front Range forest structure and composition are shaped at multiple scales by interactions among topography, natural disturbances, and forest developmental processes. This information is intended to serve as a foundation for treatment design and placement across scales.

3:20 Science, management, and implementation of forest restoration concepts: What works?
Kathie Mattor

Scientists, land managers, and stakeholders along the Colorado Front Range have worked together to co-produce knowledge and develop a science-based framework for site-specific forest restoration published in Principles and Practices for the Restoration of Ponderosa Pine and Dry Mixed-Conifer Forests of the Colorado Front Range (GTR-373). A significant outreach campaign has been coordinated to share these restoration concepts with public land management agencies in Colorado through formal and informal approaches. This talk outlines the steps taken to develop targeted outreach efforts and field workshops, including county, state and federal land management groups, private consultants and universities and presents findings of the participant evaluations of this outreach strategy. These recommendations will help to inform future restoration science and management outreach efforts.

3:40 Forest restoration on private lands in the Colorado Front Range - "Making Forests Weird Again"
Jonas Feinstein

What does it take to start with a seemingly abstract ecological framework and end up with practical guidance that yields complex forest structure in Front Range ponderosa and dry-mixed conifer forests? This presentation will provide the concrete steps using cutting-edge science and guidance the USDA - Natural Resources Conservation Service and Local Conservation Districts take in developing and implementing forest restoration projects on Private Lands across the Front Range. This is a process-based framework using climate, geology, soils, and historical forest evidence to determine historical and inform desired forest structure to achieve a variety of resource-based outcomes.

4:00 Achieving forest restoration through increased prescribed fire application.
Courtney Schultz

Forest restoration efforts in the United States often depend on the reintroduction of fire to forest ecosystems. With funding from the Joint Fire Science Program, we have been investigating the challenges and opportunities around increasing the application of prescribed fire on federal lands. In this talk, we will discuss the policy, planning, and practical approaches that are allowing units to increase their use of prescribed fire as a tool to promote forest restoration. After covering some of the common barriers and opportunities that fire managers have identified as being relevant to their use of prescribed fire, we will turn to our most recent research, which has involved case studies of management units that are successfully increasing their accomplishments. Specifically, we will present on case studies, such as the San Juan National Forest, where we have conducted interviews and reviewed planning documents to understand how these locations are increasingly their accomplishments. Based on our findings, we draw some conclusions about the most significant factors that create space for more use of prescribed fire and how these may be transferable to other units across public forest and rangelands.

4:20 – 4:25 Wrap up / announcements

4:25 – 6:30 Poster Social Ballroom CD

Poster # 1 Developing an adaptive management plan for flood restoration in Left Hand Creek Watershed

Yana Sorokin

One of the complex challenges associated with building watershed resilience is that the long- term success of restoration efforts depends on dynamic watershed processes, which are difficult or impossible to predict. One approach that shows considerable promise for addressing these challenges is adaptive management, an iterative process for informed decision-making in uncertain environments used to guide projects towards their goals. Lefthand Watershed Oversight Group developed an adaptive management plan for building the resilience of Left Hand Creek Watershed following the 2013 floods and subsequent implementation of more than ten watershed restoration projects. Our approach includes (1) conceptualizing a trajectory for resilience; (2) monitoring and assessing key watershed functions and comparing them to the trajectory; and (3) learning and adjusting based on assessments to make smarter management decisions in the face of dynamic watershed processes. By learning and adjusting, this approach will help improve watershed restoration and resilience projects by continually improving the knowledge used to design and manage these projects for the overall benefit of our community. Given the extensive watershed restoration efforts currently underway or recently completed throughout the Front Range, this a particularly pivotal time to learn from the mistakes and successes of these projects and share this information to improve future efforts.

2 Ponderosa pine regeneration after a high-intensity wildfire

Linda van Diepen

Ponderosa pine ecosystems of the western United States have been drastically altered by stand replacing wildfires over the last decade. Reestablishment of ponderosa pine forests after wildfires depends on ponderosa pine regeneration, which is governed by the amount of viable seeds, soil organic matter content and nutrient availability. Soil nutrient cycling and availability to plants is determined by the microbial community, and for seedling establishment, mycorrhizal fungi play a particularly important role. The development of mycorrhizal networks often depends on the established mycorrhizal community, which can be severely damaged by fire through heat-induced mortality. To understand the impacts of wildfire on the regeneration of ponderosa pine, we established a greenhouse experiment. Soil was collected from both burned and unburned plots six years post-wildfire from the Rogers Research Site in the Northern Laramie Mountains. Ponderosa pine seeds collected from the Laramie Mountains prior to the fire were seeded in pots filled with soil from the burned or unburned plots, and monitored for seedling emergence, growth and mycorrhizal colonization. Preliminary results show enhanced ponderosa pine seedling growth in soil from unburned compared to burned plots, indicating that high-intensity wildfires can have significant impacts on seedling regeneration. Further work will determine the potential role of mycorrhizal fungi and nutrient availability on the enhanced seedling growth.

3 Linking soil ecology with the restoration of ponderosa pine after a high-severity wildfire in the Northern Laramie Mountains of Wyoming.

Stephanie Winters

Fire-prone ponderosa pine (*Pinus ponderosa* P. & C. Lawson) ecosystems in the Western United States will be impacted by increased wildfire intensity and frequency. The soil fungal community in a ponderosa pine ecosystem post wildfire is paramount to pine seedling regeneration through their role in nutrient cycling and symbiotic relationships. In July 2012, a lightning strike started the Arapaho Fire in the Laramie Mountains. Ponderosa pines experienced 95% mortality due to the high-severity fire. Restoration treatments were set up in 2015, with which we aim to determine the most effective restoration of ponderosa pine ecosystems through implementation of pine introduction, dead wood removal, and erosion treatments. Control plots were established in areas that have living mature ponderosa pine stands remaining. All plots were surveyed for seedling presence, vegetation community, and soil nutrients and fungal diversity were measured. Results show increased ponderosa pine presence in the dead wood removal treatment 'cut and remove slash'. Additionally, increased invasive species cover is associated with decreased seedling presence. Preliminary soil results show that nitrate concentrations are higher and ammonium concentrations are lower in the control plots compared to the restoration treatment plots. Results will provide land managers with optimal treatments for restoring ponderosa pine ecosystems following high-severity wildfires.

Poster# 4 Seeing the Forest & the Trees: Habitat Restoration Assessments Using Aerobots
Richard Alward

Quantitative monitoring of ecological restoration projects is critical for assessing restoration success and realizing adaptive management programs. We are implementing the use of a sensors mounted on small unmanned aerial systems (sUAS or drones) for monitoring ecological restoration in several ecosystems, including sagebrush shrublands, pinyon-juniper woodlands, riparian galleries, and high-altitude wetlands. We used standard line point-intercept methods to sample vegetation on-the-ground to evaluate the status of (a) natural gas well pad restoration in sagebrush, (b) mule deer habitat improvements in P-J, (c) desirable vegetation recovery following tamarisk removal in riparian areas, and (d) standardized assessments of soils, vegetation, and hydrology to delineate a wetland conservation bank. Concurrently, we collected very high-resolution (5-8cm/pixel) imagery using a drone-mounted five-band multi-spectral sensor. We obtained very strong correlations between the two approaches for estimating tree, shrub, and herbaceous cover, and for distinguishing wetland from upland vegetation, using standard vegetation indices (e.g., NDVI, NDRE). We were also able to distinguish important tree and shrub species using more sophisticated image analyses (e.g., PCA, OBIA). We anticipate a large number of beneficiaries following adoption of these methods, including regulatory agencies, landowners, industrial developers, and the general public, as well as wildlife and natural ecosystems.

5 South Platte River Basin riparian Restoration
Margo Paces

The South Platte River Basin accounts for over half of Colorado's economic activity; however, tributaries in the basin are dry for large portions of the year. Historical channelization has exacerbated the problem by incising channels. An incised stream moves water quickly, preventing moisture from reaching the top banks, reducing recharge, and hindering establishment of native species. In 2015, we initiated a watershed improvement project at Denver Botanic Gardens Chatfield Farms. We installed 3 in-stream structures along Deer Creek that would re-wet historical oxbows. Along with improved habitat, restored flows have provided longer water storage in the floodplain. To evaluate the success of the structures, we initiated a long-term monitoring program. Two years post-installation, animal use increased in restored areas and water flow remained in the creek a month longer than pre-installation. Based on these successes, we aim to explore the efficiency of planting native species in riparian areas. We planted a native riparian garden along the creek in one of the historical oxbows. After two years, the site is vegetated with both species that were planted and some that arrived passively. The success of this garden will be quantified using surveys that compare the current dominant species to those planted originally. We hope to determine species that are well-suited for restoration, and to implement similar efforts in other Colorado Front Range riparian restoration projects.

6 From contamination to restoration: migratory bird habitat
Timothy Hoelzle

When hazardous substances enter the environment or oil spills occur, fish, wildlife, and other natural resource can be injured. The U.S. Department of the Interior, along with State, Tribal, and other Federal partners, acts as a Trustee for these resources. Trustees seek to identify the specific natural resources injured, determine the extent of these injuries, and identify appropriate restoration actions to compensate for their loss. These efforts are possible under the Natural Resource Damage Assessment and Restoration (NRDAR) Program, whose goal is to restore natural resources and their services that are injured by oil spills or the release of hazardous substances. Migratory birds utilize many different habitats across the globe throughout their lives, and oftentimes the best option for bringing back these populations is to implement restoration and revegetation projects far from the original source of injury. Our poster highlights projects conducted under the NRDAR Program, where habitats that supports migratory bird populations are restored throughout the United States and internationally.

Poster # 7 Impacts of forest restoration treatments on pollinator communities along the Colorado Front Range

Ryleigh Gelles

Insect pollinators are an essential component of both agricultural and wild ecosystems through the provision of pollination to the various forms of flowering vegetation, bees being the primary group responsible. However, recent research suggests a large-scale decline in bee populations, compelling the need for further research of the drivers and mechanisms influencing this decline. Within ponderosa pine forest communities, past management in the late 19th and early 20th century has led to unnaturally dense stands with closed canopies and suppressed understory production. Forest restoration goals along the Colorado Front Range align with conservationists' goals of creating desirable habitat for bees by combating the lack of resource patch connectivity, herbaceous production, and landscape heterogeneity created by these dense stands. In this study, we examined insect pollinator community response to prescribed fire forest treatments within lower-montane ponderosa pine dominated forest communities in Red Feather Lakes, Colorado. Metrics of *Bombus* and other taxonomical groups of wild bees collected between May and September within treated plots were compared to that of specimen collected within control plots. It was found that treated plots had higher bee abundance, species richness, and species diversity than samples collected within control plots, although this trend diminishes as the growing season continues.

8 The ecological effects of bark beetles, wildfires, and their interactions in Rocky Mountain subalpine forests

Zoe Schapira

Due to the shifting global climate, the frequency and severity of disturbances are increasing, causing an increase in disturbances overlapping in time and space. Bark beetle epidemics and wildfires have historically shaped the disturbance regimes of Western North American forests. Understanding their interactive effects on stand dynamics is imperative to the management and health of forested ecosystems. We focused on the effects of epidemic *Dendroctonus rufipennis* (spruce beetle) outbreaks, high-severity fires, and their ecological effects on subalpine forest regeneration in Northern Colorado. We compared seedling density and species composition across 40 sites that experienced high tree mortality from epidemic spruce beetle outbreaks, post-outbreak high-severity wildfire, or no outbreak. The study sites span multiple years post-outbreak from 1996-2017. Preliminary analysis shows no correlation between seedling densities and years since an outbreak ($p=0.1957$), indicating consistent seedling survival and regeneration of forests over time after outbreak events. Seedling densities among outbreak and control sites differ significantly from post-outbreak high-severity fire sites ($p=0.0002$), where seed availability has been severely reduced due to high mortality rates of mature seed trees. These findings can provide insight to managers for where to concentrate restoration efforts following disturbances and understanding the trajectory of recovery in disturbed high elevation forests.

9 From ridge to river: restoration lessons learned

Kent Werlin

Ecological restoration has been defined as "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed" (SER Primer, 2004). Knowledge of the target ecosystem's preexisting structure, data from intact reference ecosystems, and other principles of restoration ecology are utilized to set degraded ecosystems on a trajectory towards improved biological integrity, resiliency, stability. More than a decade of experience designing, implementing, and monitoring ecological restoration and compensatory mitigation projects in western Wyoming ecosystems, ranging from montane aspen/coniferous forests to high plains sagebrush steppe to riparian wetlands, has provided the author with many teachable moments. Restoration projects that do not provide expected outcomes can be difficult to swallow but often provide salient learning experiences. Select restoration and mitigation case studies from multiple western Wyoming ecosystems are presented. In an effort to disseminate this information to other practitioners and move the needle forward, the case studies presented here illuminate some of the ecological restoration and revegetation lessons learned along the way.

Poster # 10 Effects of grazing management and climate change on soil water storage and extent of semiarid riparian meadows
Brandon Fulcher
Field sampling and remote sensing techniques were used to assess effects of long-term uncontrolled livestock grazing and recent management improvements on riparian meadows in the upper Sweetwater River Basin in Fremont County, Wyoming. This work builds upon field research that quantified changes in soil carbon storage and the width of the wetlands by quantifying the change in wetland extent over the past 30 years using high-resolution (WorldView-2) and moderate resolution (Landsat) satellite data. Training data from the field was used to predict the current wetland extent for the WorldView-2 scenes using the randomForests R package. To quantify the change in wetland extent over the past 30 years, the high-resolution data was used to train the moderate resolution data allowing for the comparison of areas with long-term heavy and light grazing pressure to predict effects of improved grazing management on recovery of the degraded wet meadows. Results of this work will inform management and restoration of riparian wet meadows that provide important water, wildlife, and forage resources.

11 Summit Park Open Space forest restoration and fuels reduction project
Jessica Kirby
This poster will detail a restoration project that aims to improve forest health and reduce wildfire risk by restoring 300 acres of forested open space over several years of restoration. The site resides within a high-risk wildland urban interface outside of Park City, Utah and adjacent to three populated mountain subdivisions containing over 2,400 structures. The site is also home to an abundance of wildlife. The restoration focus is on improving forest health and reducing wildfire risk by the implementation of a progressive management plan on overly dense forested areas.

12 Implications of Climate Change Induced Tree Mortality on Ecosystem Function
Elizabeth Kehm
Trees are vital organisms to many ecosystems because they provide us with the oxygen we breathe, help with soil stabilization, provided wildlife habitat, sequester carbon, plus much more. With global climate change escalating, we are expected to see extensive tree mortality rates, which will lead to loss of ecological communities, and ecosystem functions and services. Specifics of potential change are unknown, but conceptual models can be used to help manage forested ecosystems under forecasted assumptions.

13 The 1 Million Tree Project: shaping landscapes and attitudes through forest restoration and community involvement
Elizabeth Kehm
Forest and residential landscapes can be negatively impacted by deforestation methods and natural disasters such as wildfires. The lack of awareness towards natural areas in need of vegetative restoration poses an issue for natural resource managers and community members that may wish to volunteer towards restoration projects but don't have easy access to information. The Society for Ecological Restoration (SER) Colorado State University (CSU) Student Guild developed the idea to plant 1 million trees through the collaboration of the community, local agencies and businesses. The scope of this project has begun within the city of Fort Collins, Colorado, but the end goal is to broaden the scale to be nationwide and potentially worldwide. The website CitSci.org has been utilized for its mapping program and as a database for trees planted, which in addition may prove beneficial to future scientific research. Recently, the SER CSU student guild has gained collaboration with the Colorado State Forest Service (CSFS) for this specific project. Our spring 2019 semester goal is to plant 1,000 trees by May 2019. By the end of this 1 million tree project, we hope to have made an impact not only on landscapes in need of tree restoration, but also on the surrounding communities through citizen, agency, and business involvement. The baseline of this project is to get people involved in planting trees in order to create more resilient ecosystems.

Poster # 14 Can native ruderal soil seed banks confer resilience against *Bromus tectorum* establishment in a semiarid grassland?

Ryan Lawrence

Previous attempts to control the invasive grass *Bromus tectorum* by seeding native perennials have been largely unsuccessful. We hypothesize that a soil seed bank of native ruderal species will improve resilience of semiarid grasslands to *B. tectorum* invasion. This research explores two corollary hypotheses: that (1) the native ruderal species we seeded will have persistent soil seed banks and (2) following disturbance, plots seeded with native ruderal species will have the least *B. tectorum* cover and biomass. In 2010, we created replicated test plots with various seed mix treatments at a disturbed semiarid grassland site in Colorado. Some plots had a native ruderal seed mix rototilled into the top 10cm of soil, some were broadcast seeded with *B. tectorum*, some received both seed mixes, and others were unseeded. To determine if there are still viable native ruderal seeds, we collected soil samples from the plots in fall 2018 and are examining their seed banks in a greenhouse experiment. So far, 75% of plots that received native ruderal seed mix have germinated native ruderal seedlings, and 21% of plots that did not receive native ruderal seed mix have germinated native ruderal seedlings. These preliminary results suggest that our native ruderal soil seed bank is persistent. If our final results still support this conclusion, we will investigate our second hypothesis by creating generalized soil disturbances in the plots and measuring plant community responses.

15 Slash pile burn effect on arbuscular mycorrhiza and soil microbial communities in a Lodgepole pine forest

Shabana Hoosein

Slash pile burns are a common method for foresters to eliminate debris left over from logging or thinning trees to prevent large wildfires. However, the consequences of these short, intense fires may be interrupting larger ecosystem processes that contribute to the lack of tree regeneration within these pile burns. Here, we investigate soil microbial processes to evaluate how ecosystem function has been influenced by these slash pile burns. We measured arbuscular mycorrhiza abundance, enzymatic activity, and substrate induced respiration. We collected our samples from two different Rocky Mountain forests across 4 subplots in relation to the burn: inside, edge, outside and intact forest. We did not see a difference between the arbuscular mycorrhiza abundance between treatments or enzymatic activity. However, we saw significant shifts in substrate induced respiration. Overall, our results indicate that microbial communities shift from native forest communities as a result of slash pile burns. Further research is needed to understand how microbial communities shift and how that affects different ecosystem processes.

16 Soil seed bank composition of a high-elevation sagebrush parkland and implications for restoration

Ryan Schroeder

California Park is a U.S. Forest Service Special Interest Area (SIA) located on the Routt National Forest, northwest of Steamboat Springs, CO. This 11,000-ha silver sagebrush park is an area of high geological, historical, scenic, and zoological values. California Park experienced severe plant community degradation in the early 1900's, the legacy impacts of which are still obvious today – including introduced plant species dominance and high soil erodibility. Ecological restoration of sites throughout California Park has occurred over the past 15 years, with mixed levels of success. The soil seed bank – those living seeds in the soil profile and on the surface – is one factor that may be limiting restoration success. In the summer of 2017, soil seed bank samples were taken from "Reference" and "Degraded" sites throughout the park and grown in greenhouse conditions from fall 2017 through summer 2018 to assess their soil seed bank community composition. Overall, 53 species were found in the soil seed bank. Mean soil seed bank species richness was 18 species for both Reference and Degraded sites, and ranged from 13 to 22 species, with a similar make-up of functional groups. Degraded sites were found to have a significantly lower total abundance of seeds, 111 seeds m-2, as compared to Reference sites, 265 seeds m-2. These data can help inform USFS resource managers as to what species may compete with restoration treatments currently on-going throughout this SIA.

Poster # 17 Irrigated and dryland pasture reclamation at a surface coal mine
Brock Bowles
The New Horizon 2 Mine is a surface coal mine located in Nucla, Colorado. Reclamation was performed contemporaneously behind the advancing pit which ranged from 50-110 feet in depth and 1,000-2,000 feet in length. The pit was then backfilled and the overburden material was graded to the final configuration to match the surrounding landscape, including re-establishing drainages. A series of underground pipelines were installed in the irrigated pasture areas to accommodate a sideroll irrigation system. Topsoil was live hauled from in front of the pit to the backfilled and graded areas behind the pit. The topsoiled areas were then seeded with an alfalfa/grass mixture or a dryland mixture, depending on the post mining land use. The irrigated pastures were designed to produce 2-3 cuttings of alfalfa/grass hay each summer and graze cattle over winter. Reference areas were utilized to measure the success of each reclaimed area. To ensure standardized results, the reclaimed areas were managed identically to the reference areas for the entire liability period. In 2014 and 2015, the reclaimed irrigated and dryland pastures areas were sampled and statistically demonstrated that both areas exceeded the 90% cover and production standards set by the corresponding reference area. In June 2018, New Horizon 2 was granted full bond release on these 272 acres and the pastures were returned to the 6 private landowners who will continue to farm the pastures as they did before the mine.

18 Integrated ecological restoration planning and monitoring at the Little Saint Francis River chat pile site
Matthew Struckhoff
The Little St. Francis River chat pile site in southeast Missouri is a historical lead and zinc mining waste site being remediated and restored as part of a Natural Resource Damage Assessment and Restoration settlement. To catalyze and improve restoration implementation at the 50 hectare site, we heeded calls from within the restoration ecology community to integrate restoration planning with long-term monitoring design. Site reconnaissance related coarse extant community types to potential restoration targets identified in USDA Ecological Site Descriptions to identify three broad goals: bottomland forest restoration on the remediated chat pile site, upland woodland habitat improvement, and invasive plant species reduction. Restoration monitoring was designed to quantify changes in plant community attributes relevant to these goals. Pre-restoration vegetation sampling quantified plant community composition, enabled refinement of restoration objectives and identification of management strategies appropriate for Ecological Site Descriptions and yielded maps to visualize baseline invasive species abundances and inform eradication planning. Continued invasive species sampling will enable rapid, map-based quantification of changes in abundance and identify locations where additional eradication efforts are needed. Long-term community composition monitoring will relate restoration progress to specific restoration methodologies and inform adaptive management recommendations.

19 Documentation of baseline conditions for subalpine fen restoration at Midnight Meadows using unoccupied aerial systems
Matthew Struckhoff
As part of a Natural Resource Damage Assessment settlement related to contaminant releases from the Molycorp/Questa Molybdenum mine, subalpine fens, wetlands, and associated stream habitat for the native Rio Grande cutthroat trout are being restored in high-altitude headwaters of Bitter Creek, in the Midnight Meadows management area of Carson National Forest, New Mexico. Working with the US Department of the Interior's Office of Restoration and Damage Assessment, the USDA Forest Service, and the Amigos Bravos water conservation organization, US Geological Survey scientists collected imagery during September 2018 using unoccupied aerial systems (UAS, or "drones") to document degraded upland and wetland vegetation and stream channel conditions during the early stages of restoration. The UAS missions demonstrated the utility of the UAS platform near its published air density altitude limits. Photogrammetric processing of images yielded a 3D point cloud, a digital surface model, and an orthorectified, mosaicked image of the high-altitude fen complex. These products document current conditions and provide baseline data for monitoring 1) the restoration effectiveness of erosion control structures based on terrain changes, 2) hydrologic changes in the creek and contributing fens, and 3) changes in vegetation composition and structure. Ongoing collaboration is identifying additional ways in which UAS data can complement on-the-ground vegetation and habitat monitoring.

Poster # 20 Revegetation using cushion plants after recreational trampling on a Colorado Fourteener
Rachel Kreb

Cushion plants are candidates for alpine trail revegetation because of their adaptation to extreme environmental conditions, their ability to persist in disturbance, and their role in facilitating other plants. This 7-year study monitored cushion plant transplants used to restore a closed trail on Mount Yale. The transplants lived until 2015, but all died by 2017. However, due to recruitment from the nearby community, in the final monitoring year, the cushion plant population in the trail increased to 156% of its baseline population. In the final year, we assessed the diversity and abundance of cushion plants and the plants facilitated in their canopies. The most dominant cushion species was *Minuartia rubella*, followed by *Minuartia obtusiloba*. The most dominant, facilitated species was *Festuca brachyphylla*. Elevation ($p=0.859$), slope ($p=0.703$), and soil moisture ($p=0.745$) did not influence the composition and abundance of cushion plants recruited in the trail (NMDS ordination). However, the composition and abundance of their canopies' plants were influenced by soil moisture ($p=0.001$) and elevation ($p=0.005$), weakly influenced by slope ($p=0.052$), and not influenced by size of cushion plant ($p=0.347$) (NMDS ordination). Findings suggest cushion plant recruitment is promising and not limited by elevation, slope, and soil moisture. This study also suggests that cushion plants facilitate plants with a range of different elevation, slope, and soil moisture preferences.

21 Post-fire wood mulch increases tree seedling establishment with minimal impacts on understory plant community development following high severity wildfire
Jayne Jonas

Following the 2012 High Park Fire in Colorado, we initiated a study to understand impacts of post-fire mulching on ecosystem recovery. Mulches were applied to a lodgepole pine forest burned at high severity in a randomized complete block design immediately following the fire; plant and soil monitoring occurred from 2012 to 2016. Treatments included wheat straw, wood strands, and wood shreds applied at two coverage rates, and two controls (synthetic mulch, no mulch). Our results indicate that mulch type was more important than application rate for most ecosystem responses. The overriding pattern of understory plant recovery was an increase in total cover and shift in composition over time unaffected by mulching. Non-native understory species were not abundant at the end of this experiment, but their cover was higher in plots treated with wheat straw and high rate-wood strands compared to no mulch control. Lodgepole seedling densities were higher with wood shreds and synthetic mulch than with wheat straw and no mulch. Because we saw few effects of mulch treatments on plant available nitrogen, it is likely that effects on soil abiotic conditions drove this lodgepole response. Our findings indicate wood mulches can provide soil protection for many years and accelerate lodgepole pine establishment following wildfire. As reported by others, we also found that wheat straw may facilitate non-native species establishment and spread while also limiting lodgepole regeneration.

22 The development and application of uniform hydroseres in riparian and wetland restoration: a means of increasing resolution in the design phase and enhancing success in the construction phase.
John Giordanengo

The distribution of plants across floodplains is influenced by flood frequency, hydrology, soil conditions, and other variables. The consistency of these variables over space and time can produce predictable hydroseres (i.e., zones) across floodplains. While practitioners are tasked to communicate designs for a diversity of stakeholders and to develop formulaic design methods for a wide range of conditions, approaches to defining restoration hydroseres vary greatly and can lack necessary detail for stakeholders and construction firms. Hoag and Fripp (2005) defined riparian zones for southwest systems based on flood return intervals. Merritt et al. (2010) developed vegetation-flow response guilds, grouping species with shared traits such as life history, morphology, adaptations to fluvial disturbance, etc. And a variety of unpublished approaches also exist. Riparian zonation systems that prescribe revegetation extents relative to a hydrologic reference (i.e., bankfull) has practical implications. Because floodplains encompass a broad range of geomorphic conditions (i.e., cut banks, benches, etc.), designs based on general terms like "riparian", "bench", or Zone can be misleading, lead to reductions in revegetation detail, or result in locating plants where their chance of survival is poor. Based on experience from over 30 riparian projects across CO, this talk presents a formulaic approach to defining restoration hydroseres, shares technical tips, and provides case studies.

Poster # 23 National and regional native seed programs: 2019 updates
Gregory Eckert
The National Seed Strategy, initiated in 2015, has progressed through a wide range of bottom-up and top-down activities. The Strategy focuses on increase and availability of "workhorse species" to address invasive plant management and post-catastrophic event revegetation needs. We provide examples of progress from around the US reflecting Seed Strategy goals for a) Needs and Capacity, b) Science, c) Decision Tools, and d) Communication. We also provide updates on the National Academies Seed Need Survey design and implementation. We will use the Southern Rockies Seed Network as an example of opportunities and challenges in developing regional and sub-regional seed networks. Copies or links to Seed Strategy-related reports and materials will be available.

24 Project opportunities between SER and the National Park Service
Gregory Eckert
The National Park Service and the Society for Ecological Restoration signed a Cooperative Agreement in 2018 to support cooperative restoration work. Specifically, the objective of this Agreement is to expand the capacity of the National Park Service to conduct and cooperate on high quality ecological restoration, and to share information about those efforts with the public. NPS will work with SER's chapters and sections to engage government and non-government organizations, universities and private stakeholders into conservation stewardship activities beyond park boundaries. We will present ideas for Conference participants to discuss: A) Building SER's Restoration Resource Center database. B) Participation by NPS staff in SER chapters and theme based sections. C) Partnering to conduct research on NPS restoration projects. D) SER student members participating with/interning on NPS restoration projects. E) Promotion of NPS restoration activities and issues to a broad audience of public and private restoration practitioners and researchers. F) Cooperative projects to apply and provide feedback to SER regarding SER's new International Standards for the Practice of Ecological Restoration.

25 Case Study of In-Situ Seed Harvesting in Restored Grasslands to Increase Native Seed Availability
Derek Tilley
A Woodward Flail Vac seed harvester was utilized to harvest slender wheatgrass (*Elymus trachycaulus*) from a restored grassland at Grand Teton National Park. Seed was harvested over three continuous days covering an area of approximately 13.6 ac. Total seed yield was 642 bulk lb or equivalent to 47 bulk lb/ac. Estimated hours of labor for three days of harvesting plus time processing came to 120 hours. When comparing the resources and environmental inputs required for in-situ seed harvesting to the conventional native seed production, given an appropriate setting, in-field seed harvesting may offer a viable additional method to supplement native seed need and may offer an effective, affordable, and environmentally sustainable alternative of procuring significant amounts of seed of locally adapted ecotypes for restoration plantings.

26 Common Ground: National Park Service Denver Service Center Transportation Division Roadside Revegetation Practices
Kenneth Stella
As a result of National Park Service (NPS) policy and federal regulations NPS Denver Service Center Transportation Division (DSC-T) has incorporated ecological restoration principles into road repair and construction projects since the mid-1980's. Initially revegetation was difficult because of a lack of appropriate plant materials and poor construction practices. To increase availability of genetically appropriate native plant materials and transfer revegetation technology an interagency partnership with Natural Resource Conservation Service (NRCS) Plant Material Program was established. This interdisciplinary partnership capitalizes on the common conservation missions of both agencies to accelerate revegetation of disturbed areas in National Park units and continues to evolve nearly 30 years later.

Poster # 27 Plant conservation on public land in New Mexico
Laura Shriver

New Mexico supports a remarkable array of native plant species. Diverse landscapes and an elevation range of over 10,000 feet give rise to the fourth highest floristic diversity in the country. The New Mexico Bureau of Land Management (BLM-NM) manages over 13 million acres of land and has a robust Plant Conservation Program. Managing public land involves collecting and analyzing ecological data to make well informed adaptive management decisions. The national Assessment, Inventory, and Monitoring (AIM) Program streamlines and standardizes monitoring activities on public lands. BLM-NM has six AIM crews collecting data on soil characteristics and plant diversity. BLM-NM is also part of the Southwest Seed Partnership (SWSP), a collaboration started in 2015 by the Institute for Applied Ecology (IAE), BLM-NM, and Region 3 of the Forest Service to improve the supply and diversity of native plant materials in the Southwest. The SWSP develops target species lists, collects wild seed, and works with farmers to increase wild-collected seed in seed production fields. Seed that comes off of production fields will be made available for restoration projects. Lastly, with over 12% of New Mexico's plants considered at risk, the Rare Plant Monitoring Program establishes long-term monitoring plots for rare plant species to understand population trends in order to prevent population decline. This poster will discuss impetus and impacts of the BLM's Plant Conservation Program in New Mexico.

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SCHOOL OF ENERGY RESOURCES

Wednesday March 13

7:30 AM — Registration / Coffee — Outside Ballroom AB

8:30 – 8:35 — Welcome / announcements — Ballroom AB

8:35 – 9:55 Organized Session 2: 2013 Flood Recovery Efforts Through the Colorado Emergency Watershed Protection Program

Moderated by Kevin Hauck

8:35 Management and oversight of Colorado Emergency Watershed Protection Program for 2013 Colorado flood recovery.

Chris Sturm

In September 2013 massive flooding occurred across Colorado's Front Range communities. The Colorado Water Conservation Board (CWCB) led the effort to repair, re-align, and restore the flood affected rivers, streams, and floodplains. As the Statewide sponsor of the Natural Resources Conservation Service (NRCS) 2013 Phase II Emergency Watershed Protection (EWP) Program, the CWCB was tasked with overseeing and implementing $50 million in stream recovery work. The CWCB also participated in the implementation of another $20 million in stream recovery work funded through other programs including the U.S. Dept of Housing and Urban Development's (HUD) Community Development Block Grant – Disaster Recovery program. The State Department of Local Affairs (DOLA) and the CWCB created a Watershed Resiliency pilot program with the HUD funds, creating capacity in local watershed coalitions, developing resiliency recovery plans, providing stream designs, and constructing projects. Following the 2013 floods, CWCB developed comprehensive watershed and stream master plans that emphasized natural stream function and ecosystem health along with property and infrastructure protection. In total, 117 projects representing nine Front Range Watersheds were restored between March 2015 and May 2018. The purpose of our presentation is to present on the specific restoration and challenges of implementation for 65 miles of streams, rivers, and floodplains.

8:55 Implementation of Colorado's Emergency Watershed Protection Program for 2013 flood recovery.

Katie Jagt

In September 2013 flooding occurred across Colorado's Front Range communities causing circa $4 billion in damage. The Colorado Water Conservation Board (CWCB) led the effort to repair, re-align, and restore the flood affected rivers, streams, and floodplains. Under CWCB, Jeff Sickles, Principal of Enginuity, was tasked with leading the Resilience Watershed Partnership Technical Assistance Team to assist Emergency Watershed Protection (EWP) Program Flood Recovery. As such, Jeff and his team assisted with the completion of 116 projects in 9 affected watersheds. Between March 2015 and May 2018 over 65 miles of stream and river improvements were implemented with total construction costs of $70 million. Through the NRCS and CWCB, Jeff and the Technical Assistance Team worked with over 700 private property owners, with near-term damage reduction of $270 million. In total, project implementation was coordinated through 28 different project sponsors, including watershed coalitions, special districts, and local governments. This presentation will focus on how, as a team, NRCS, CWCB and the Technical Assistance Team were successfully able to deliver the EWP Program on-time and under budget.

9:15 The good, the bad, and the ugly of creating and implementing a short time-frame plant materials program for Colorado flood recovery.

Randy Mandel

The 2013 Front Range flooding occurred between September 9 to September 15, 2013 when a slow-moving cold front stalled over Colorado. The resulting heavy rain caused catastrophic damage over an approximately 200 miles range, affecting a total of 17 counties. The Colorado Emergency Watershed Protection Program was created to provide funding to implement emergency recovery measures to address hazards to life and property for the flood affected areas. Phase 2 of the program was funded and administered by the USDA Natural Resources Conservation Service and managed by the Colorado Water Conservation Board with total resources of $63.2 million and a project time-period from Spring 2016 to Spring 2018. To provide the necessary plant materials for revegetation, a portion of this funding was used to create an ecotypic plant materials program. This talk will discuss the specifics of creating a technically sound program on a such short time-period, focusing on successes, challenges, and necessary compromises to meet the needs of approximately 116 recovery projects over a two-year period. Propagule collection and increase of over 70 species, as well as the storage, provision, and implementation of close to 1000 lb of site-specific seed, 227,000 containerized stock, and 61,000 cuttings will be discussed in detail.

9:35 Panel Discussion Moderated by Kevin Hauck

9:55 – 10:30 — Break — Ballroom CD

10:30 – 11:50 **Technical Session 2: Case Studies**

Moderated by Randy Mandel

10:30 Restoring populations of threatened *Physaria* species endemic to the Piceance Basin
Jayne Jonas

The unique habitats of two threatened mustards (*Physaria obcordata, Physaria congesta*), endemic to the Piceance Basin of Colorado, occur in an area of energy development. Although efforts have focused largely on protecting critical habitat, climate change and continued development pressures may require alternative strategies to ensure their long-term persistence. We initiated a field study to determine the best approach for establishing new populations of each species in suitable but unoccupied habitats within their native range. Three sites <600 m and three sites >600 m from natural populations were established for each species. We examined establishment of seeds planted in fall 2014 and success of greenhouse-grown seedlings planted either in fall 2014 or spring 2015. Through May 2018, establishment from seed has been limited to less than 5% in both species. After three years, survival of transplants of both species is generally higher for individuals planted in the spring than those planted in the fall. Some evidence indicates that distance to natural populations may affect *P. obcordata* establishment. Flowering was first noted in May 2016 for both species; by May 2018, up to ~80% of P. *congesta* survivors flowered. In May 2018, three *P. congesta* and one *P. obcordata* recruits were identified. Although continued monitoring is needed, our observations suggest that it may be possible to establish self-sustaining populations of these rare endemic species in suitable habitat.

10:50 Post-fire restoration of Wyoming big sagebrush within the Douglas Greater Sage-grouse Core Population Area.
Jana White

Natural recolonization and regeneration of Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) within wildfire-impacted landscapes of eastern Wyoming can take decades or even centuries. For this reason, efforts to preserve and restore the eastern edge of the sagebrush ecosystem are integral to preventing further contraction of this ecosystem and the range of sagebrush-obligate species, such as the Greater Sage-grouse (*Centrocercus urophasianus*). In 2014, the Douglas Core Area (DCA) Restoration Team (Team) began targeting wildfire-impacted areas to investigate strategies for restoring sagebrush to post-wildfire areas within a Greater sage-grouse core population area in eastern Wyoming. Projects have consisted of outplanting 100,000+ greenhouse-grown sagebrush seedlings across 5000+ acres. Annual project monitoring results highlight the importance of using locally collected seed to grow sagebrush seedlings and directly confronting environmental challenges such as competition, soil moisture constraints, and herbivory in project design and implementation. We will present results on seedling survival, growth, and reproduction during the initial years following project implementation. In addition, we will describe ongoing research into the longer-term persistence of sagebrush seedlings after project infrastructure is removed and seedlings are exposed to ambient environmental conditions and land management practices.

11:10 Adoption of simple and effective ecological restoration techniques in a high-altitude floodplain impacted by hard rock mine waste.
Andrew Harley,

Minnie Lynch Mine, an abandoned mine site at 10,300 feet, lies within the Bonanza Mining District, CO and contributes flow to Kerber Creek via an intermittent drainage. Environmental impacts include flow from two collapsed adits, heavy metals, unstable mine waste, distressed vegetation, and a geomorphically unstable channel. The work was divided into three phases. This case study focuses on 2016 restoration of the lower portion of the drainage. Over 1,000 cubic yards of mine waste was removed from the channel followed by consolidation and revegetation through amendment incorporation. Channel reconstruction through this section included installation of an EPDM liner to capture channel water while adit water was redirected through a limestone rock trench. Approximately 600 feet of channel below the adit was reshaped to the confluence with Rawley Gulch plus two acres of floodplain reclamation. Channel improvements included increasing sinuosity in the channel, and construction of limestone rip rap check dams and log vanes to manage flow and reduce channel erosion. Floodplain revegetation included lime and organic amendments ripped to maintain a rough and loose surface configuration to reduce surface velocities, trap spring runoff, and provide for a diversity of plant life and productivity. Graded streambanks were protected with biodegradable erosion mats along with large woody debris scattered throughout the site to enhance ecosystem diversity.

11:30 Landscape typology: a case study of data-driven conservation in an urban environment.
Allison Robinson

Understanding the relationship between natural ecosystems in urban environments, or urban ecology, has grown in importance as the world's cities rapidly expand and change. The City of Denver has experienced unprecedented population growth and at the same time, an increasing ambition to preserve native landscapes and enhance Denver's park system. To inform land management decisions, Denver Parks and Recreation (DPR) needed to develop a methodology to quantitatively assess ecosystem function within consistently defined urban ecotypes. The Landscape Typology process establishes spatially defined urban ecotypes found within each individual park and provides tabular data on multiple urban ecosystem parameters for each ecotype. Using this data, DPR is able to optimize urban conservation using adaptive management strategies and maximize efficiency when allocating restoration resources. Furthermore, the Landscape Typology program allows the user to quantitatively measure changes in ecosystem function over time, which provides insight into the success of individual restoration projects, as well as large-scale park design. The Landscape Typology results are formatted as a geodatabase that aims to maximize accessibility of information by decision-makers, parks employees, and the public. A demonstration dataset from DPR Open Space will be presented to show what data is collected and how it can be used to inform conservation and ecological restoration decisions in an urban environment.

11:50 – 1:20	Lunch	Ballroom CD
12:30 – 1:15	High Altitude Revegetation Committee Meeting	Rm 322
12:40 – 1:15	Lory Student Center & CSU Sustainability Tour	Meet at Registration table

1:20 – 2:50 **Keynote Session 2**

Moderated by Pete Stahl

1:20 Keynote 2: Historical reference conditions, species pools, and functional traits: the future of western mixed conifer forests.

Daniel Laughlin

Restoration ecologists have an innate desire to restore what has been lost. Our first instinct is to use historical reference conditions as empirical benchmarks for restoration success. However, historical reference conditions in many regions are undefinable and are increasingly viewed as irrelevant under climate change. The important question to ask is why were species dominant historically? The answer, presumably, is because they exhibited traits that conferred high fitness in those environments. As the environment changes, optimal traits may shift, making historical trait distributions less fit and ill-suited for the task. If this is the case, then we may need a new framework for setting targets to meet desired functional outcomes in ecological restoration in a rapidly changing world. In this talk I will compare and contrast the use of historical reference conditions with those based on functional traits in a fire-adapted mixed conifer forest on the North Rim of Grand Canyon National Park. This forest has increased in tree density since the age of fire suppression, which makes it more susceptible to stand-replacing crown fire. I will show how management actions designed to restore historical conditions work remarkably well to enhance forest resilience, but will also discuss alternative options that might lead to success in a hotter, drier climate.

1:50 Expanded genetic variation in prairie sunflower inter-population crosses for potential native plant restoration in variable environments.

April Goebl

Restoring native plant communities in degraded habitat is particularly challenging when environmental conditions are highly variable. Revegetation of sites with unpredictable conditions must consider both successful establishment in current conditions & persistence under varying future environments, making selection of source materials non-trivial. Starting with high genetic variation can serve to genetically bet-hedge when variation in inter-annual conditions is high. To investigate the effects of increased genetic variation, we compare performance of inter- & intra-population crosses of *Helianthus petiolaris*. *H. petiolaris* is an annual, native sunflower that typically inhabits prairies & has been proposed for restoration of degraded land on the Colorado Plateau. This species presents a good system to investigate: Does increased genetic variation in inter-population crosses improve average fitness across a range of conditions? To address this question, we crossed 4 *H. petiolaris* ecotypes from locations with varying climates for 2 generations. We planted & tracked a total of 3200 seeds from inter- & intra-population crosses in cleared plots at 2 common garden sites with replicated water treatments. Throughout the annual life cycle we measured fitness components for all plants. I will present data from this experiment to help inform on the importance of genetic variation in the context of restoration in variable environments.

2:10 Seed ecology of restoration-relevant forb species: phylogeny and climate influence inter- and intraspecific variation in germination.

Alexandra Seglias

Seed dormancy and germination traits can be constrained by phylogenetic history, which can lead to the assumption that related species have similar traits. However, significant intraspecific variation in these traits is also present due to adaptation to local climatic conditions. Understanding sources of both species- and population-level variability can be useful when planning for restoration projects to ensure that seed is sourced from the most appropriate site. We examined the relationships between phylogeny, climate, and seed germination traits for 24 populations of eight native, restoration-relevant forb species from the Southwest United States. The seeds were exposed to eight treatments designed to mimic regional climatic conditions. Phylogenetic relatedness, climatic conditions, and temperature conditions at the source site were all significantly correlated with final germination response, with significant intraspecific variation in germination response for seven of our eight study species. Notably, when analyzing germination during stratification, precipitation seasonality was found to be the only significant predictor of variation in germination, and all eight species showed significant intraspecific variation. Our results suggest that this trait should be considered in germination studies as well as seed sourcing decisions.

2:30 Intraspecific trait variation of restoration grass seedlings at early developmental stages.

Magda Garbowski

In recent decades, models based on plant functional traits have been used to predict how plant communities will respond to abiotic and biotic perturbations. Species trait values from published literature or large databases that are most often obtained from mature plants are typically used to inform such models. These values may not be appropriate for understanding community processes of restored systems for two reasons: (1) trait values from different populations of the same species may vary and (2) trait values of mature plants may not reflect seedling traits that are important for establishment and survival. To address these concerns, we measured traits of grass species commonly used in arid land restoration (*Elymus trachycaulus*, *Hesperostipa comata*, *Muhlenbergia porteri*, *Vulpia octoflora*) from several populations at different ontogenetic stages and compared them to trait values from the TRY Plant Trait Database or values published in the literature. We found that mean trait values as well as population-level trait variability differed by population, trait measured, and ontogenetic stage. A better understanding of variation in grass seedling traits may inform restoration seed source selection as well as improve the use of models for predicting restoration outcomes.

2:50 – 3:10 Break Ballroom CD

3:10 – 4:30 Technical Session 3: Forest Restoration Moderated by Magda Grabowski

3:10 Collaborative forest restoration and fire-risk reduction on Colorado's wildland-urban interface: scaling up through interagency cooperation.

Andrew Rayburn

The Colorado Front Range wildlife-urban interface (WUI) is a dynamic managed landscape undergoing rapid changes due population growth, increasing development, wildfire and other disturbances, recreation pressure, expansion of water supplies for large municipal areas, climate change, and land conservation efforts by organizations such as Jefferson County Open Space (JCOS). In Jefferson County, JCOS manages ca. 45,000 ac. Of land spanning 29 open space parks, many of which lie within forested portions of the WUI that are densely populated and at high or extremely high risk of catastrophic wildfire. With the dual goals of restoring forest habitat and reducing wildfire risk, JCOS implements large-scale forest management projects in collaboration with local, state, and national partners to capitalize on funding opportunities and to achieve broader impacts. At Flying J Ranch Park, JCOS is collaborating with Denver Mountain Parks, the Colorado State Forest Service, the Colorado Forest Restoration Institute, contractors, youth groups, and volunteers on a multi-year project to restore ponderosa pine savanna and mixed conifer stands while reducing wildfire risk within the park and creating a landscape-scale fuel break to protect surrounding communities. We will provide a project overview, focusing on the benefits of interagency collaboration at various stages, and describe how this project is serving as a model for JCOS in other forested areas of the park system at risk from wildfire.

3:30 Colorado & New Mexico disasters: utilizing NASA Earth Observations to quantify forest mortality and burn severity to inform management on ranches and open lands.

Sophia Leiker

Both wildfires and forest insect outbreaks have increased in frequency and severity in recent years. Western spruce budworm (*Choristoneura freemani*), a widespread defoliator in western U.S. forests, has affected over 6,000 hectares of forest in south-central Colorado since 1998. Aaron Swallow, an environmental ranch manager in southern Colorado, is concerned that fuel loading from budworm-related tree mortality will increase the risk of catastrophic wildfire on the lands he manages. To address this concern, we selected a study area encompassing the 2018 Spring Creek Fire footprint. Then, we used NASA Earth observations to: 1) analyze and map regional tree mortality prior to the 2018 Spring Creek Fire; 2) quantify and map burn severity for the Spring Creek Fire; and 3) model the relationship between pre-fire tree mortality and burn severity of the fire. We identified key predictor variables with the Variable Selection Using Random Forests (VSURF) R package and modeled pre-fire tree mortality using the randomForest R package. Burn severity was mapped using the Relativized Burn Ratio (RBR). The maps created from this project provided our partners with a comprehensive assessment of tree mortality, facilitating future restoration and management efforts. Additionally, an accompanying methods tutorial will enable our partners to replicate this analysis for other years, locations, and forest disturbances.

3:50 Effects of collaborative restoration and adaptive management on forest structure and composition in the Colorado Front Range.

Kevin Barrett

In response to large, severe wildfires across the western US, federal initiatives have been enacted to increase the pace, scale, and quality of ecological restoration in frequent fire forests. The Collaborative Forest Landscape Restoration Program (CFLRP) supports landscape-scale restoration while emphasizing collaborative and adaptive approaches to forest management. The Colorado Front Range Landscape Restoration Initiative (LRI) was selected as a CFLRP grant recipient in 2010 with the goal of treating 13000 ha of ponderosa pine-dominated forests over a 10-year period across the Pike and San Isabel and the Arapaho and Roosevelt National Forests. Here, we assess stand level desired conditions across 14 projects and a 6-year evaluation period to determine to what extent restoration treatments contribute to desired conditions, and assess whether adaptive management processes contribute to reaching restoration goals regarding forest structure and composition. Results indicate that restoration treatments are moving forests toward desired conditions regarding residual forest structure, however further reductions in the relative abundance of Douglas-fir may be warranted. Adaptive management processes appear to be effective, as more recent projects better match desired conditions compared older projects, including further reductions in Douglas-fir to meet forest composition objectives.

4:10 Modeling the effects of heterogeneous restoration treatments on understory light environment in a mixed-conifer forest.

Jeffery Cannon

Restoration treatments in dry conifer forests often seek to restore the heterogeneous forest structure that historically characterized these stands. Thus, it is crucial to understand how changes in forest spatial structure alter abiotic conditions to improve predictions of how spatially variable treatments impact regeneration response to changes in resource availability. We used hemispherical canopy photography in a stem mapped mixed-conifer forest to model light availability across a forest density gradient using a model selection approach. Using the stem map, we simulated a range of restoration treatment scenarios varying in spatial complexity and applied the model to evaluate how each treatment impacted light availability. We found that light availability was best predicted by forest structure at multiple scales roughly corresponding to crown diameter and vegetation height. Additionally, we found that simulated restoration treatments with the highest aggregation led to 7% higher net light availability relative to random thinning and had the most variability in light availability. Further, spatially aggregated treatments resulted in the most area with high light availability and the least area with low light availability. Thus, we expect that spatially complex restoration treatments may favor light environments conducive to shade-intolerant species such as ponderosa pine over Douglas-fir while maintaining high overstory spatial heterogeneity.

4:30-4:35 Wrap up / announcements

Thursday March 14

7:30 AM	Registration / Coffee	Outside Ballroom AB
8:30 – 8:35	Welcome / announcements	Ballroom AB
8:35 – 9:55	**Technical Session 4: Wildlife**	Moderated by Drew Rayburn

8:35 Insect response and dispersal associated with restoration in a semi-arid natural gas field.
Michael Curran

Insects, the most diverse animal group on Earth, provide a wide-array of ecosystem services. However, 'the little creatures that run the world,' are often underappreciated in restoration and conservation studies. Aside from providing biodiversity, insects are critical pollinators and sources of food for higher trophic levels. Four years of field studies have shown insects respond positively to restoration efforts on well pads in the Jonah Infill and Pinedale Anticline natural gas fields. While the first three years of field work focused on collecting insects on well pads with various vegetation communities and comparing them to insects found in adjacent reference systems clearly showed insects are attracted to reclaimed well pads, determining whether insects disperse from well pads was not an objective. The fourth year of field work involved using immuno-marking techniques to determine whether insects are using revegetated well pads as resource islands or sinks. Here, we demonstrate how insects respond to and disperse from well pads undergoing restoration activity.

8:55 Ponderosa pine forest restoration can benefit avian communities.
Latif Quresh

Fire suppression has increased stand density and risk of severe, stand-replacing wildfire in ponderosa pine forests. The U.S. Forest Service's Collaborative Forest Landscape Restoration Program (CFLRP) aims to restore ecological disturbance processes and improve conditions for biodiversity. We applied the Integrated Monitoring in Bird Conservation Regions program to survey birds in relation to CFLRP treatments along the Colorado Front Range in 2015–2017. We estimated species occupancy and richness at 292 points nested within 54 1km^2 grid cells. The data supported 38 species occupancy relationships with treatment, 22 of which were consistent with hypothesized mechanisms for treatment effects. For example, grid-level occupancy for aerial insectivores increased with percent area treated, which related positively with extent of open forest (10–40% canopy cover), where they forage. In contrast, point-level occupancy for shrub nesting species was lower at treated points, which had less shrub cover. We found both positive and negative point-level relationships with treatment, but only positive grid-level relationships with percent area treated (1km-radius neighborhood). Accordingly, grid-level species richness peaked at ~60% area treated. These results suggest CFLRP treatments can benefit communities by generating habitat for open-forest species without necessarily eliminating habitat for closed-forest species, although we may maximize benefits by maintaining some dense stands.

9:15 Enhancing wildlife habitat through snag recruitment during forest management projects: initial results and future directions.
Steve Murdock

Snags are key structural elements in Front Range forests that provide critical food resources and nesting sites for wildlife. Snags and other coarse woody debris are also important for nutrient cycling, seedling facilitation, stand complexity, and for understanding historical stand dynamics. Snag retention and recruitment are emphasized as elements of forest restoration frameworks in Colorado, with management objectives often including target numbers of snags per acre to be retained and/or recruited. Snag recruitment can result from natural processes such as pathogens, insects, lightning, and fire, as well as from manual treatments such as girdling, topping, prescribed fire, forest pest pheromones additions, and herbicide application. We present the results of a three-year pilot study testing three snag recruitment methods (girdling, topping, and herbicide) begun in 2015 during the implementation of a ponderosa pine enhancement project by Jefferson County Open Space (JCOS) staff at Alderfer / Three Sisters Park in Jefferson County, Colorado. The degree of insect and woodpecker use was recorded annually for each treatment, and both have been generally higher for girdled trees. Study results are guiding snag recruitment efforts in JCOS forest management projects, and staff are planning an expanded study with greater replication to investigate the influence of additional factors such as tree age, height, diameter, and site characteristics on snag recruitment outcomes.

9:35 Considerations for large scale sage grouse habitat improvements.
Jesse Dillon

Projects on federal land must consider compensatory mitigation in situations where potential impacts to the species habitat cannot be avoided or minimized. Two proponent-driven compensatory mitigation projects for Greater Sage Grouse were proposed recently in northern Nevada, for land areas between 20,000 and 230,000 acres. Both projects used a data-driven framework to select focal areas for conservation. GIS-based analysis of breeding, late brood rearing, and winter habitat data along with lek locations and telemetry data; vegetation cover and pinon-juniper encroachment, fire frequency, soil erosion factors, land management and permitted uses, habitat continuity, and topographic data, were used to evaluate the best treatment areas to achieve habitat uplift. Using the best available science, targeted treatments included Pinon Juniper thinning, inter-seeding with desirable grasses and forbs, and weed control. Implementation of treatments required digital tracking technology and real-time data visualization and management. This presentation will demonstrate the screening process to select the treatment areas, discuss the preliminary treatments to be implemented, and introduce habitat improvement goals. Based on our experiences, we present considerations for large scale land restoration data management, technology applications, and project tracking to streamline implementation and reach success factors as they pertain to mitigation programs for the benefit of sage-grouse.

9:55 – 10:30 Break Ballroom CD

10:30 – 11:50 Organized Session 3: Can Broad-Scale Wetland Restoration Help Mitigate the Impacts of Climate Change? Results of 10 Years of Implementation.

Moderated by Jeremy Sueltenfuss

10:30 Wetland restoration at the Valles Caldera National Preserve: techniques and vegetation response.

Steven Vrooman

The Valles Caldera National Preserve in the Jemez Mountains of Northern New Mexico is the newest additional to our National Park System. The Preserve has thousands of acres of high altitude valleys that have been heavily impacted by human uses such as grazing, logging and road building. This area has also been impacted by a number of large wildfires that have burned over 2/3rds of the Preserve. For the last 10 years, Los Amigos de VC has worked with funding from the US EPA, New Mexico Environment Department and private foundations to restore the wetlands and streams of the Preserve. A large number of low-cost effective techniques have been developed, tested and monitored to restore wetlands cheaply and effectively. We have also partnered with Los Alamos National Laboratory and Global Conservation Assistance to test the effectiveness of these restoration methods for treating post-fire runoff by the use of stable isotope techniques. We propose that large-scale low tech restoration techniques can be an effective tool to mitigate the impacts of human disturbance and climate change.

10:50 Buffering of hydrological and geochemical impacts of climate change and drought: examples from plug and pond restorations at the Valles Caldera National Preserve.

Brent Newman

Studies of plug and pond type watershed restoration have shown that these kinds of remediation activities drive profound changes in the hydrology and biogeochemistry of treated watersheds. The resulting increases in water storage, groundwater levels, and hydrological residence times as well as changes in redox conditions as a result of plug and pond activities help buffer impacts from climate related affects such as droughts and fires. This presentation will explore the kinds of positive changes that plug and pond restoration imposes using geochemical and stable isotope data from treated watersheds within the Valles Caldera National Preserve in New Mexico, USA.

11:10 Biodiversity accounting for extractive industry net-positive impact goals, can wetland restoration improve biodiversity gains.

Kina Murphy

Mining causes abrupt and extensive forms of land-use change. It not only impacts biodiversity, it destroys ecological processes and causes land degradation that has cascading effects on whole systems. Recently, development banks have adopted performance standards that require the extractive companies they provide with loans to show that they are having a net-positive impact on biodiversity. This has resulted in the creation of core biodiversity monitoring programs that focus on accounting for biodiversity gains and losses. However, these programs often only focus on specific species. We suggest that disturbances to abiotic factors, such as water and soil, should be included in core biodiversity monitoring because they are critical to the survival of all species. Erosion and the subsequent loss of shallow ground water tables are threshold triggers that can be used to identify broad-scale disturbances and climate drivers that affect ecosystem resilience in impacted landscapes. Watershed degradation from erosion, caused by land-use change, is a worldwide issue that impacts the ability of landscapes to support biodiversity. Erosion causes loss of topsoil and diminishes the capacity of landscapes to store water. This reduces primary productivity, baseflow in streams and leads to loss of wildlife habitat, grazing and farming resources. Examples are given that show how restoring ecological processes, such as wetlands, is the most effective mechanism for increasing biodiversity.

11:30 Panel Discussion Moderated by Jeremy Sueltenfuss

11:50 – 1:20 Lunch Ballroom CD

12:45 – 1:15 Student – Professional Mixer LSC Room 386

1:20 – 2:50 **Keynote Session 3**

Moderated by Brett Wolk

1:20 **Keynote 3: Fire, Climate change and adapting restoration ecology to a changing world**

Don Falk

Species have a variety of mechanisms for adapting to climatic variation over a range of time scales, but the current pace of climate change may exceed the adaptive capability of many species as currently distributed. Ecological disturbances, such as wildfires and insect outbreaks, operate at time scales many times faster than even the accelerated climate velocity of the current century. Disturbances are transient processes that can trigger significant and irreversible environmental, demographic and ecosystem change. These interactions of climate change and elevated levels of disturbance constitute the greatest challenge for restoration of terrestrial ecosystems now and many decades into the future. A consensus is emerging within the restoration field that a focus on ecological resilience, rather than strict interpretation of historical reference conditions, may best enhance the adaptive capacity of many ecosystems. Departures from historical references should be undertaken cautiously and incrementally, respecting the importance of ecological legacies, refugia, species interactions, and unexpressed genetic variation. We can decompose ecological responses to disturbance across a spectrum from persistence and recovery to system reorganization, and introduce a theorem of resilience relevant to the formidable challenges in a rapidly changing world.

1:50 Policies to support forest and fire restoration efforts.

Courtney Schultz

Fire ecologists, policy makers, and managers recognize that we in the Western United States need to promote more fire on forestlands and undertake restoration efforts at more contiguous and larger spatial extents. How can we promote such efforts through policy tools? Research by the CSU Public Lands Policy Group has investigated this question over the last several years. In this talk, I will provide an overview of what we have learned about policy tools to support landscape restoration, and then turn specifically to our recent work on policy barriers and opportunities around the application of prescribed fire. After briefing covering findings from the first phase of our research, looking at trends across the West, I will turn to findings from a local case study—the San Juan National Forest. I will discuss findings from our interviews and document analysis about the factors that are allowing the forest to grow their prescribed fire program. This talk will conclude with some broader observations about policy tools and the role of multi-level governance strategies to support the restoration of fire-adapted forest ecosystems in the Western United States.

2:10 Understory vegetation changes in the decade following the Hayman Fire, Colorado.

Paula Fornwalt

At more than 52,000 ha, the 2002 Hayman Fire remains the largest wildfire known to burn in Colorado, USA. I synthesize results from a group of papers that used pre- and longer-term post-fire data to examine how understory vegetation composition changed in the 10 years after the Hayman Fire, and how changes related to fire severity. Understory composition exhibited longer-term resilience to pre-fire conditions following low-severity burning, despite experiencing some initial changes. Meanwhile, following high-severity burning, understory composition changed initially from pre-fire conditions and continued to move away from them as time passed. Both an initial loss of pre-fire species from the local community, and a continued recruitment of new species, drove compositional changes in areas experiencing high-severity fire. Species that were locally lost following high-severity burning tended to (1) have northern-temperate biogeographic affinities, (2) have long-lived (perennial) life spans, (3) be forbs, and (4) be native to the continental United States. Species that were locally recruited tended to (1) have southern-xeric biogeographic affinities, (2) have either short-lived or long-lived life spans, (3) be either graminoids or forbs, and (4) be either native or exotic to the continental United States.

2:30 Effects of seed source on drought performance and implications for native prairie restoration: a multi-species greenhouse drought experiment.

Katherine Fu

Local provenancing is the most widespread seed sourcing approach in ecological restoration because local seed populations are assumed to possess local adaptation to the environmental conditions of the restoration site. However, contemporary climate change can alter selective pressures such that local populations will no longer be best adapted. Therefore, seed sourcing from populations adapted to predicted future climatic conditions may result in greater restoration success, but these populations must be able to establish in current and future conditions for successful restoration. In Colorado and much of the Southwest US, drought frequency, duration, and severity are expected to increase. To understand how performance of wild-collected and cultivar plant populations in drought conditions relates to the climatic conditions of their collection sites, a greenhouse study with three watering frequencies (control, mild drought, and severe drought) was conducted on seven plant species commonly used in North American native prairie restoration. For each species, plant height, growth rate, and above-ground biomass was compared across 6 wild and 1-2 cultivar populations in the 3 watering treatments. This project informs guidelines for seed sourcing; ideal source populations perform well across all drought treatments, while for populations that do not differ in their performance, any of these populations may potentially be used to achieve reasonably similar restoration outcomes.

2:50 – 3:10 Break Ballroom CD

3:10 – 4:30 **Technical Session 5: Invasive species**

Moderated by Becky Hufft

3:10 Native annual and biennial species can compete with an aggressive invasive grass.
Carla DeMasters

Bromus tectorum L. (cheatgrass) is the most widespread and problematic annual brome grass in the western United States, dominating more than 40 million hectares of rangeland in the Intermountain West. Areas of *B. tectorum* dominance are extremely difficult to restore via seeding with traditional seed mixes consisting of perennial grasses and forbs. Introduced annual species like *B. tectorum* are better able to germinate early, grow rapidly and allocate resources to aboveground biomass compared to late seral species like perennial grasses and forbs. The theory of limiting similarity postulates that functionally similar native species, those species that rely on the same set of ecological resources, may compete more strongly for resources with non-native annual invasive species than perennials. We tested the ability of native annual and biennial forb species to persist in competition with cheatgrass. Seedling establishment rates show that some of these native annual and biennial species proved themselves capable of coexisting within stands of *B. tectorum* and may be good candidates for inclusion in restoration seed mixes. The results of this experiment will help to inform *B. tectorum* management and current restoration practices.

3:30 Pothole seeding for cheatgrass control in early restoration.
Danielle Johnston

Restoration efforts in arid western ecosystems is often hampered by cheatgrass (*Bromus tectorum* L.). In prior research, we found that soil surface obstructions reduce the dispersal of cheatgrass seeds, and that a roughened, or 'potholed' surface can reduce cheatgrass biomass during early restoration. Here, we explicitly test the impact of a potholed surface on cheatgrass seed dispersal, and report on the development of a new implement to create the pothole surface. Using fluorescently marked cheatgrass seeds, we found that a potholed surface reduces cheatgrass dispersal 2- to 3- fold as compared with a flat surface. The magnitude of potholing's effect far exceeded that of brush mulch, which reduced dispersal by only 20%, and only when combined with potholing. We manufactured a third prototype tool to create the pothole surface efficiently. This tool combines the three seed boxes of a Truax™ Flex II ® rangeland drill with large notched discs, and is capable of creating the pothole surface and seeding in a single pass. We treated 10 ha with the new tool in August 2018 at Escalante State Wildlife Area near Delta, CO. Good germination of seeded species was evident within potholes by November 2018.

3:50 Fungus to the rescue: Canada thistle biocontrol.
John Kaltenbach

A statewide release and monitoring program conducted by the Colorado Department of Agriculture has shown that a highly host-specific rust fungus, *Puccinia punctiformis*, can control Canada thistle. The fungus has been found in North America for well over a century and it is well documented that it can kill Canada thistle. The main barrier to using it as an effective biological control agent is the difficulty in getting it established in a thistle patch. The Colorado Department of Agriculture has now developed effective protocols for establishing the fungus and the next steps will be to refine methods for using the fungus for Canada thistle control, develop management practices to enhance the activity of the fungus and teach end users how best to use the fungus in restoration, conservation and production situations. A description of the rust life cycle and dynamics in a patch of Canada thistle is discussed, as well as methods for detection, monitoring, collection and redistribution. Results of monitoring are presented and future plans for the utilization of this "new" agent will be shared.

4:10 Pile burn scar restoration at Lily Lake: tradeoffs between abundance of non-native and native species.
Ian Sexton

Accumulation of fuels in forests across the Western United States is producing larger, more severe wildfires. To decrease wildfire severity and increase forest resilience, foresters remove excess fuel by burning woody material in piles. This can also cause persistent ecosystem changes that include alteration of soil properties, due to soil heating, which can favor invasive species. Native plant abundance and species richness may remain depressed for years after burning has removed vegetation and diminished propagules. This adds to the vulnerability of burned areas, which can transition to invasive plant dominance. Research on the use of revegetation in forests to suppress invasion is limited. Studies conducted in woodlands that investigated revegetation of pile burn scars have had varying success. To assess pile burn scar restoration in Rocky Mountain National Park, we monitored vegetation in 26 scars in 2014. Later that growing season we selected 14 scars for restoration that included soil scarification, seed addition, and mulch cover. Following restoration, seeded species cover exceeded surrounding unburned areas. This suppressed cover of non-native species and native species that were not seeded in 2014. It also suppressed the growth of a native forb that was planted three years after restoration. We conclude that restoration of scars can be a useful tool that will likely need to be part of an integrated pest management program addressing other infestations near scars.

4:30 – 4:45 Closing remarks/Awards — Mark Paschke, Michael Curran, Pete Stahl

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